RESTORATION OF A PORTABLE KYMOGRAPH

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ABSTRACT

The presence of an old portable kymograph in the Phonetics and Phonology Laboratory (LPP) of La Sorbonne Nouvelle gave the idea for a restoration project. Alexis Rygaloff purchased a portable Gauthier kymograph for field investigations in China around the middle of the 20th century. The kymograph (about 10 kg) consists of a recording cylinder moved by a clockwork mechanism associated with a Foucault regulator. The clockwork mechanism is connected to a drive bar by means of a belt placed on two wheels, one connected to the mechanism and the other to a drive bar. The registering devices (Marey's drums) built by Verdin are attached to a trolley fixed on a foot connected to the bar. The regulator allows to choose different movements (slow, medium, fast) depending on the nature of the experiments that are planned.

Keywords: Kymograph, Clockwork mechanism, Foucault regulator.

1. INTRODUCTION

At the beginning of the 17th century, Galileo was concerned with representing sounds graphically. Nevertheless, acoustic analyzes of the sounds' descriptions began before their graphic representations. We owe the first acoustic analyzes to Lissajous in 1857. The graphic representation of uniform sounds of short duration is linked to the invention of the *chronograph*, and Young, as early as 1807, showed his students a graphic recording of the sound vibrations of a tuning fork.

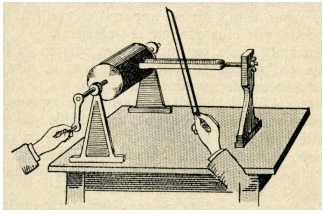

Figure 1: A picture of Thomas Young's from [1] p.4.

Another chronograph which constitutes an improvement on Young's model is the *vibrophone* invented by Duhamel in 1840. The major contribution of this device is the addition of a tuning fork-chronograph, which brings a precise temporal reference. This contribution allowed Marey to represent other phenomena graphically and no longer in a uniform way. This biologist who claimed as early as 1868 that all the sciences could be represented graphically, launched the starting point for the first recordings of speech for the purpose of sound description [2].

The kymograph belongs to the family of speech recorders in the same way as the *phonotaugraph* and the *phonograph*. The former allows the visualization of speech sounds, the latter is used to archive them. The speech recorder is inseparable from the speech recorders which are better known as *Marey's drums.* The recorder is the plane that records and traces the movements in the form of oscillations induced by the inscribers.

In this paper, we will describe the mechanism of a portable kymograph used by Rygaloff for field studies in China. We will also show the importance of the adjustment of the speech inscribers (Marey's drums) and the speed of rotation (Foucault regulator) which are fundamental elements to obtain interpretable and reproducible tracings.

2. HISTORY

2.1. Recording speech movements

The first trace of a device recording a graphic representation related to the measurement of time is linked to the use of the *kymographion* described by [3] to reproduce the activity of blood vessels in living animals. The originality of this device is linked to the fact that the brush color is changed with each turn of the cylinder, the lines are superimposed and can be fairly easily distinguished. The limit of this device is related to its use, which requires vivisection and therefore cannot be used in fields other than animal physiology [4]. In order to be able to represent the exact form of a pulsation and to represent it with a unit of time, Marey undertook the construction of a system based on the *kymographion* and the *sphygmograph* of Vierordt. He ended up with Chauveau in the development of a system called cardiograph which shows the importance of the inscribers which he will call levers.

At the same time, it was at the time when the abbot Rousselot wondered about devices that could help him to characterize phonetic phenomena by taking into account the speed parameter. He wondered about the interest of the cylinder and the speed of its drive [5: 76]. We will return to these notions in section 3.
The device selected by Rousselot which seemed to be the most suitable for recording the movements of speech was nothing other than the recording cylinder with clockwork and regulator mechanism built by Verdin, presented on the first page of his catalog of precision instruments [6]. This is, in our opinion, the first version of the apparatus which will later be called the kymograph.

2.2. Movement inscribers

To represent a movement faithfully, whether in terms of length, force or duration, implies that the marker used is reliable and precise [4] This started from the mechanism of Scott de Martinville's phonautograph (1857), a thin membrane which vibrates differently according to the influence of the sounds. The vibrations of this membrane are transmitted to a stylus which rubs on the smoked surface of a rotating cylinder. Marey [2], developed several inscribers of different movements like the transmission myograph, which in our opinion is closer to the needs of the more complex mechanisms of speech is the transmission myograph (p. 196). This is at the origin of the lever drum or Marey's drum used with the kymograph described in this paper.

3. PORTABLE KYMOGRAPH

3.1 Gauthier Kymograph

The Gauthier's portable kymograph (*Fig. 3*) consists of a stainless-steel drum (a) on which the paper is fixed, a Foucault regulator (b and *Fig. 4*), and a drive bar (c) on which the recording drums are positioned. This apparatus can be transported in a small wooden box (*Fig. 2*). Small boxes with the accessories necessary for the proper functioning of the kymograph can also be placed in the wooden box. The accessories are: a metal mouth mask, olives of different sizes, glass tubes for measuring nasal pressure, and laryngograph for laryngeal vibrations (*Fig. 10*). Recording drums of different diameters are associated with this set. These accessories can be connected to the recording drums by rubber tubes. Hollow straws, pens for scratching the paper, ink pens, glue, wooden pinches for handling the paper and adjustable tuning forks are also part of the apparatus.

Figure 2: Gauthier portable Kymograph and its travel box.

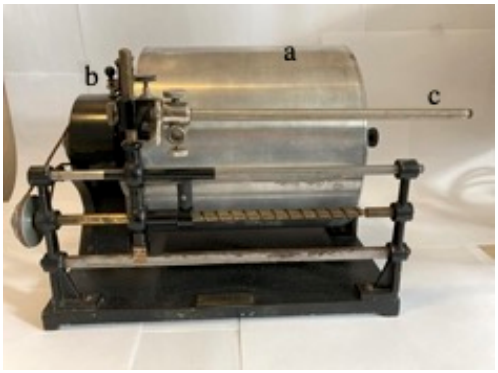

Figure 3: Gauthier Kymograph parts: a) drum, b) Foucault regulator, c) drive bar.

3.2 Foucault Regulator

At the end of his life, Foucault was especially known for the construction of regulators, initially intended to stabilize the drive of lighthouses, and telescopes. A huge quantity of regulator models can be found in the "Recueil des Travaux Scientifiques de Léon Foucault" [7].
The regulator is made up of a spring-loaded clockwork mechanism that winds up with a key. It is connected to a drive bar through a belt placed on two wheels, one connected to the clockwork mechanism and the other to a drive bar. The recording devices are attached to a trolley fixed on a foot connected to the bar. The controller can allow to choose different speed movements (slow, medium, fast) depending on the nature and the precision of the experiments to be made. The clockwork gives the cylinder 3 different speeds (*Fig. 4*), 1 and 8 revolutions per second and 1 revolution per minute. A brake placed on the regulator frame allows it to be started and stopped at will. The regulator itself consists of a disk with 4 adjustment masses which regulate the rotation of the drum. To adjust the regulator, it is possible count the number of revolutions that the cylinder performs in a

given time. Once the right speed has been chosen, it is noticed that the first revolutions are irregular, but that after the rotation of the drum becomes more regular. The last rotation is also irregular because of the braking imposed by the regulator.

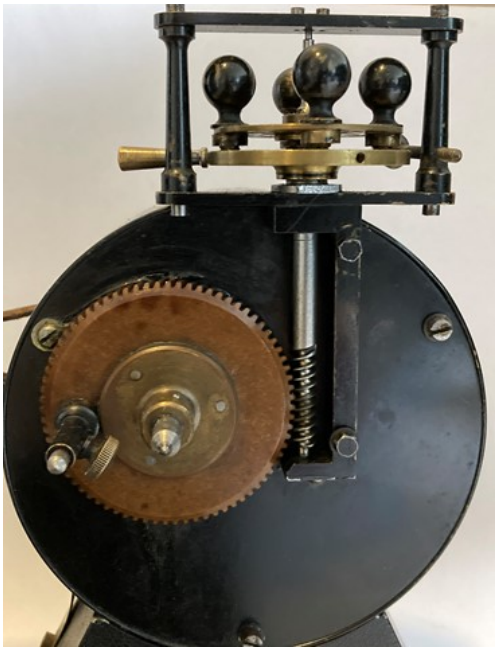

Figure 4: Drive wheel at the output of the clockwork mechanism and Foucault regulator.

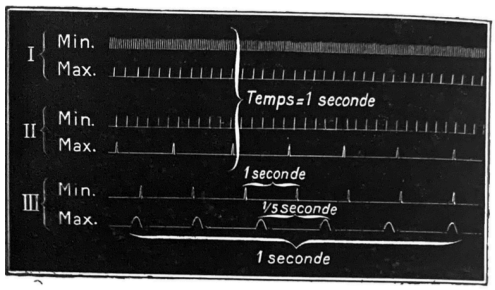

Figure 5: Illustration to explain the 3 possible rotation speeds of the Foucault regulator from [8]

The recording apparatus which we have just described does not, therefore, have a uniform speed of rotation. It is, therefore, necessary to associate it with a tool allowing to have a reliable time base. The means adopted for a portable kymograph is the use of a tuning fork. A light feather is attached to the end of one of its branches, which allows direct measurement of its vibrations at the same time as the traces are obtained on the paper placed on the drum. An adjustable tuning fork provides 25 or 50 Hz vibrations that are suitable for slow movements. A tuning fork tuned for vibrations between 200 and 1000 Hz is associated with rapid movements.

Blackened paper is placed on the drum. The blackening of the paper is obtained either by a small torch or by the smoke coming from a candle with a thick wick which gives a thick black smoke. This candle called *cellar rat* (Rat de cave in French) is placed under the drum which is rotated on itself to blacken the entire sheet of paper. There were devices simplifying the smoking system where the smoke of cellar rat was distributed under several cylinders that were turned manually (*Fig. 6*).

Another method employed to inscribe the paper was to leave the paper white and obtain black lines with ink placed in a quill at the end of the straws placed on the inscribing drums.

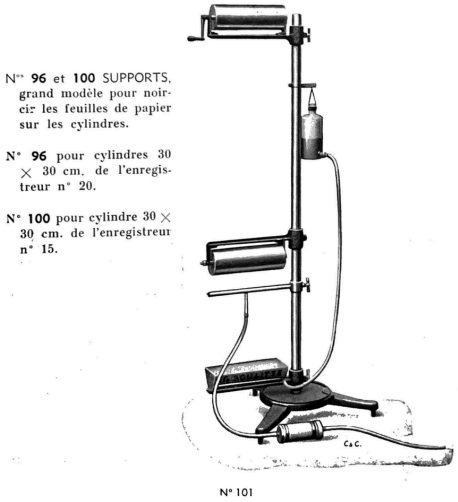

Figure 6: Smoke holder from [8]

Lever drums consist of a metal tank closed at the top by a thin rubber membrane with some tension (*Fig. 7* & F on *Fig. 8*). They carry a metal tube that opens inside and fits a rubber tube (C in *Fig. 8*). The air that passes through the tube and enters the tank and lifts the rubber membrane. On the membrane an aluminum disc is glued and connected with a lever which is articulated by one of its ends to a small straw placed in the extension of the axis (E in *Fig. 8*). This joint allows the lever to perform vertical movements. The straw is equipped with a pen that traces on the smoky paper the movements induced by the membrane [4].

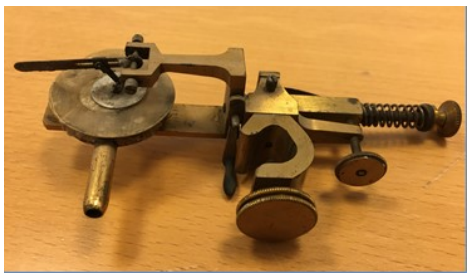

Figure 7: Marey's drum built by Verdin used with our kymograph.

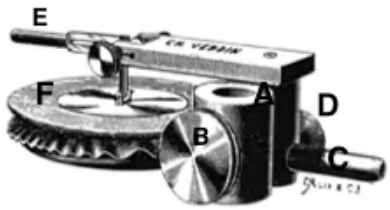

Figure 8: Marey's drum with rubber cover (F), hole to fix the drum on drive bar (A), Adjustment knob (B & D), bar to put the straw which is used to mark the cylinder (E), tube through which the air passes (C) [8] p.26.

Once the assembly of the drum is done, it is necessary to choose the point of the cylinder where the inscription will take place, which amounts to adjusting the position of the drum and that of the carriage. The feather placed at the end of the straw should touch the surface of the blackened paper.

4. RESTORATION STEPS

The first restoration step of this kymograph was to make the clockwork mechanism work again and to test the various parts involved to make it work. We also had to test the tension of the drive belt to have a continuous and regular rotation.

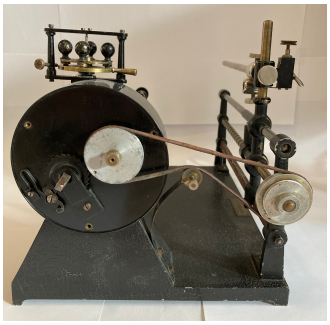

Figure 9: Belt, rolling disks, and drive bar.

Once the regulator of Foucault was put back in operation, we tested the various instruments allowing to capture the differences in air movements that we had at our disposal: the nasal olives for the air passing by the nose, the mouthpiece for the air passing by the mouth and the laryngograph with a double bowl of Zund-Burguet; two drums whose membrane is raised by springs, fixed together and opened into a Y-shaped pipe, described in the catalog [9].

a b c

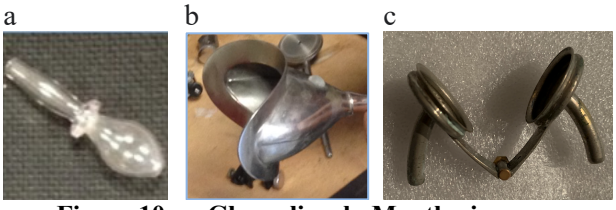

Figure 10: a. Glass olive, b. Mouth piece, c. Laryngograph

The second restoration step was to attach the tabs to the bar, to space them far enough apart so that the curves would not overlap, and to find an effective angle for the straws to scrape the blackened paper. The different instruments (*Fig. 10*) allowed us to test different stiffnesses of the membrane attached to the drum, different bending angles of the straws, and different speeds of the controller, see *Fig. 11* for the complete setup used and *Fig. 12* to see the obtained plots.

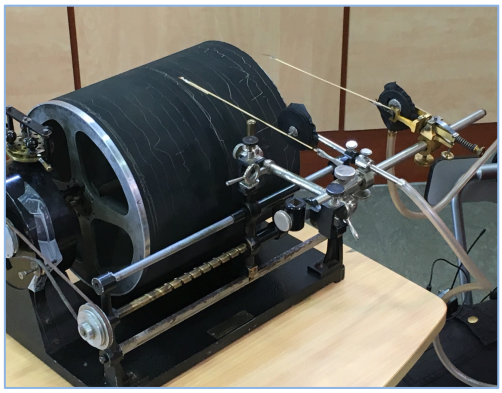

Figure 11: Complete Kymograph with 2 Marey's drums, straws and pen on blackened paper.

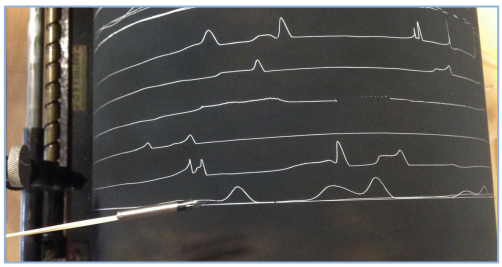

Figure 12: Straw with pen scratching blackened paper.

The next step in this restoration process is to test the instruments (the same ones used by Rousselot and recently restored) with the kymograph in an attempt to reproduce the experiments made by Rousselot at the end of the 19th century.

5. ACKNOWLEDGEMENTS

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