Botany. — *"On a new clinostat after* DE BOUTER". By Prof. F. A. F. C. WENT.

(Communicated at the meeting of December 30, 1922).

It has been known to every botanist for more than 15 years, that the clinostats in present use are not satisfactory with regard to great precision. Already in 1907 VAN HARREVELD [1]) made the errors of those instruments known to us in a detailed study. He himself constructed a much better clinostat, satisfying high requirements, but nevertheless introduced only in a few laboratories. This will be chiefly due to the great costs, unsurmountable for most laboratories.

To the above fact it has been chiefly due, that Mr. P. A. DE BOUTER, mechanic of the Botanical Laboratory at Utrecht, asked himself, whether it would not be possible to construct a much cheaper clinostat, nevertheless coming up to high requirements. Those considerations have led to the construction of a new clinostat, the description of which follows.

Fig. 1 shows the clinostat in a more or less schematic way. 1 is a shuntmotor, running directly full speed, and connected by a belt 3, with a flywheel 2, to the axis of which a pinion has been fixed. With the aid of cog-wheels its motion is transmitted to the proper clinostat 5. The axis of the fly-wheel turns on ball-bearings. Now the question is, to make this fly-wheel revolve exactly once a second; this cannot be attained by altering the speed of the motor or by regulating the diameter of the grooved wheels because of a too great oscillation of the voltage of the town-plant. Neither does the motor run regularly with equal voltage; namely with excentric load. For this reason a different construction has been used here.

Into the circuit + — of the motor a resistance 12 has been inserted in the form of a lamp, in consequence of which the fly-wheel runs a little too slowly, e.g. half a rotation a second. If however this resistance is put out of circuit, the fly-wheel revolves a little too fast, e.g. two rotations a second. This putting out takes

[1]) PH. VAN HARREVELD, Die Unzulänglichkeit der heutigen Klinostaten für reizphysiologische Untersuchungen. Recueil des Travaux botaniques néerlandais. III. 1907, p. 173.

place every second with the aid of the pendulum of a clock keeping exact time.

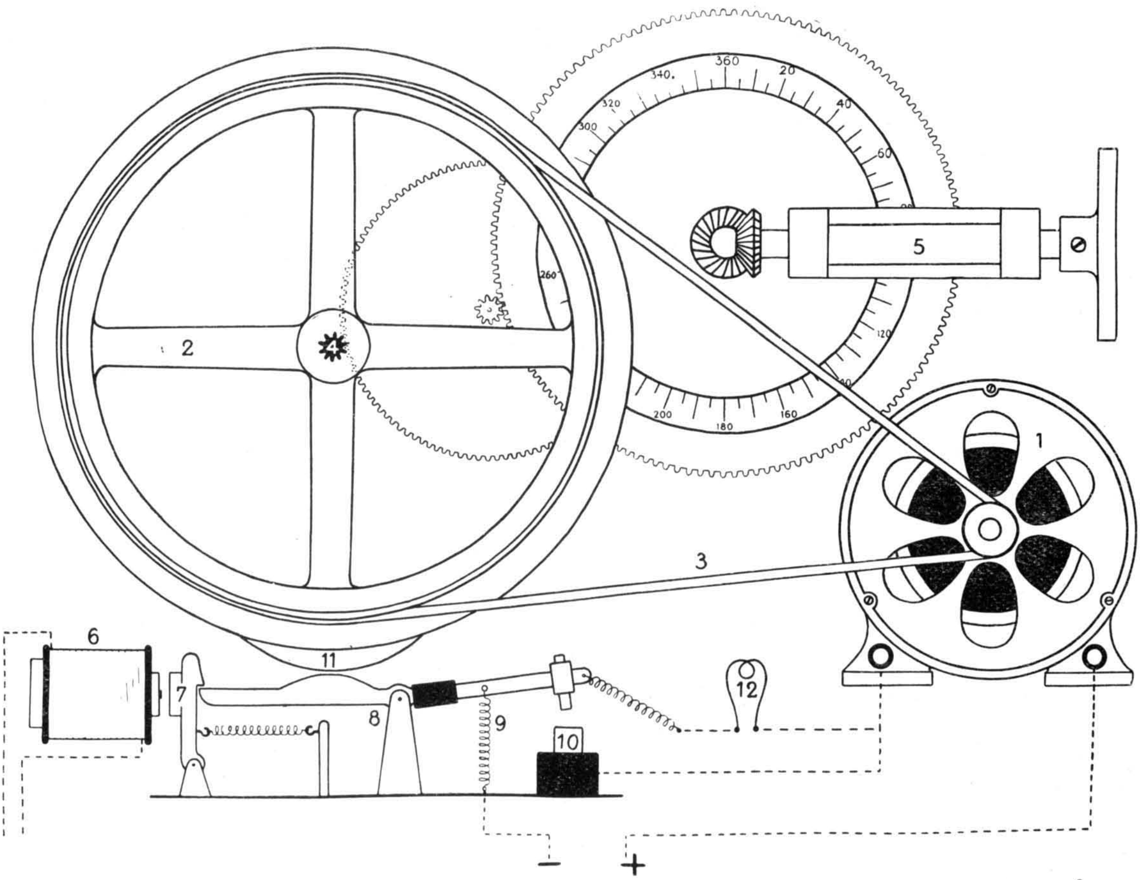

Fig. 1. Sketch of the new clinostat; description in the text.

At 6 we see an electro-magnet every second turning magnetic for an instant and attracting the spring-armature 7. The turning-over switch 8 is drawn to one side by the spring 9, in consequence of which the contact 10 is made. The current passes from + through the motor straight to contact 10, next through a part of the switch 8, through the spring 9 and finally to —; in this way the motor runs full speed.

But on the fly-wheel a cam 11 has been fixed; this makes the switch 8 catch behind the armature 7, in consequence of which the circuit is broken at 10. Then the current has to pass through the resistance and the motor runs slower.

The final result is that the fly-wheel makes exactly one revolution a second. Even considerable oscillations of the voltage of the light and power-station are of no consequence, the only result will be, that the cam 11 is a little more to the right or to the left at the moment, at which the second circuit is closed, so that only the ratio of the rapidly and slowly revolving parts of the axis of the fly-wheel may be altered every second. This is of no importance, because the axis of the clinostat revolves at a much slower rate and the movement is transmitted to this by means of the cog-wheels 4, etc.

To the horizontal axis of the clinostat a conical cog-weel has been fixed, in which another conical cog-wheel catches, fastened to an adjustable axis 5. This latter axis has been fitted on in such a way, that it can revolve on the horizontal axis and can be fixed, while the rotatory movement is not impeded. This enables us to give the axis of the clinostat any desirable position. By fixing the adjustable axis and releasing the adjusting-apparatus, a rotation of the plant perpendicular to the horizontal axis may be obtained. This arrangement is shown in fig. 2; the adjustable axis is fastened with the screw *A*, the adjusting-apparatus with the handle *B*.

Fig. 3 gives a backview of the whole apparatus, in which the arrangement of fig. 2 has not yet been fitted on. This figure shows, that the apparatus is comparatively small and may easily be removed by one person. The position of the axis too may be modified without any difficulty during the experiment.

To the simple construction it is owing that the costs of purchase are considerably lower than of any other satisfactory clinostat. An objection is, that the motor keeps running throughout the experiment and therefore constantly uses current. But then the axis revolves with great power, so that considerable weights can be carried, while excentric loading that is rather considerable, does not cause any alteration in the regular running of the clinostat.

In order to check the running of this clinostat and compare it with PFEFFER'S and VAN HARREVELD'S, clinostats, the recording-apparatus of the auxanometer of KONINGSBERGER [1]) was used.

For this purpose electrodes were fixed to the axis of the clinostat either right opposite to each other or at an angle of 90°, in such a way, that after each full rotation of the axis, the top of such an electrode once made contact in a mercurydish and in this way a circuit was closed for a short moment. Closing that circuit caused a writing glass-pen to be stopped in its course and to be

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[1]) V. J. KONINGSBERGER, A method of recording growth under various external influences. Proceedings Kon. Ak. v. Wet. Amsterdam. W. en Nat. Afd. XXX, 6/7. 1921.

sent back to its starting-point, while a drum with paper, on which the recording occurred, was moved on 1.5 mm.

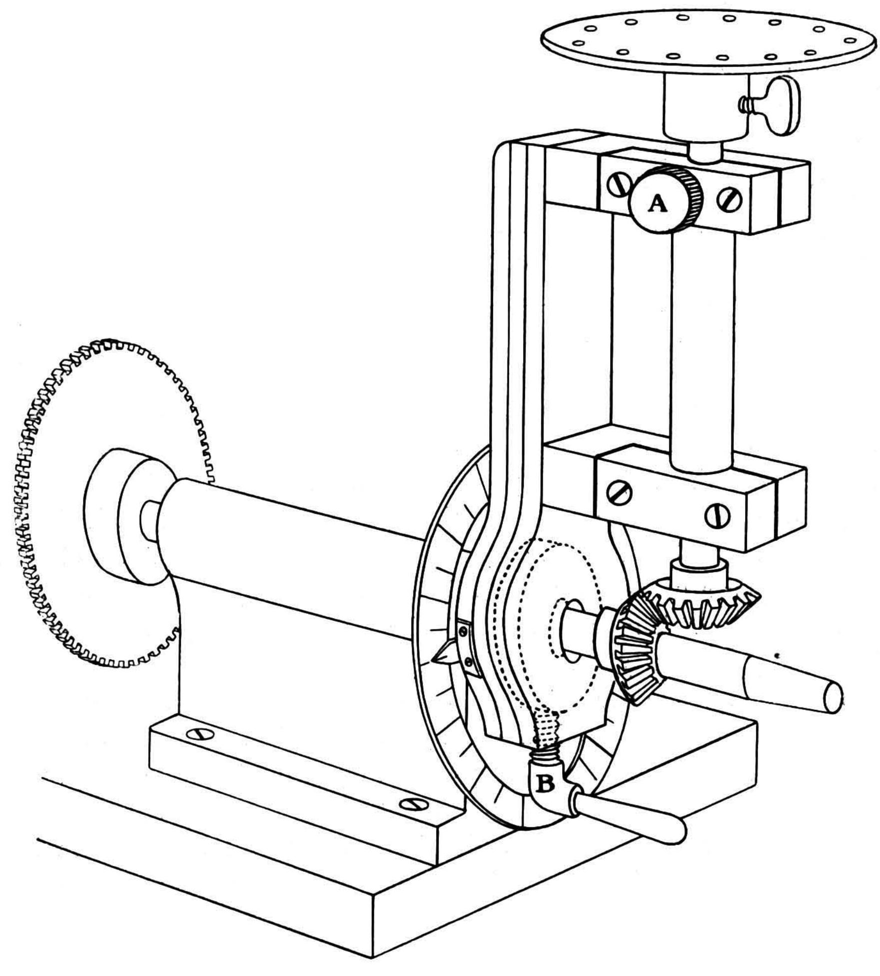

Fig. 2. Top of the clinostat-axis with conical wheels, as described in the text.

The pen moves along the paper with a velocity of 1 mm. a second, writing a straight line. A number of parallel lines arises in this way, as shown in fig. 4, drawn for so many seconds as the period amounts to, needed by the clinostat-axis to make a half or a quarter of a rotation.

If therefore the clinostat runs regularly, these lines must be of equal length, or may differ one second at most, with respect to the point of time at which the contact with the mercury is made.

In the figure something else has been recorded: every 6 minutes a time-signal is given on a continuous line T. Of course the distance covered by the circumference of the clinostat-axis in successive 6

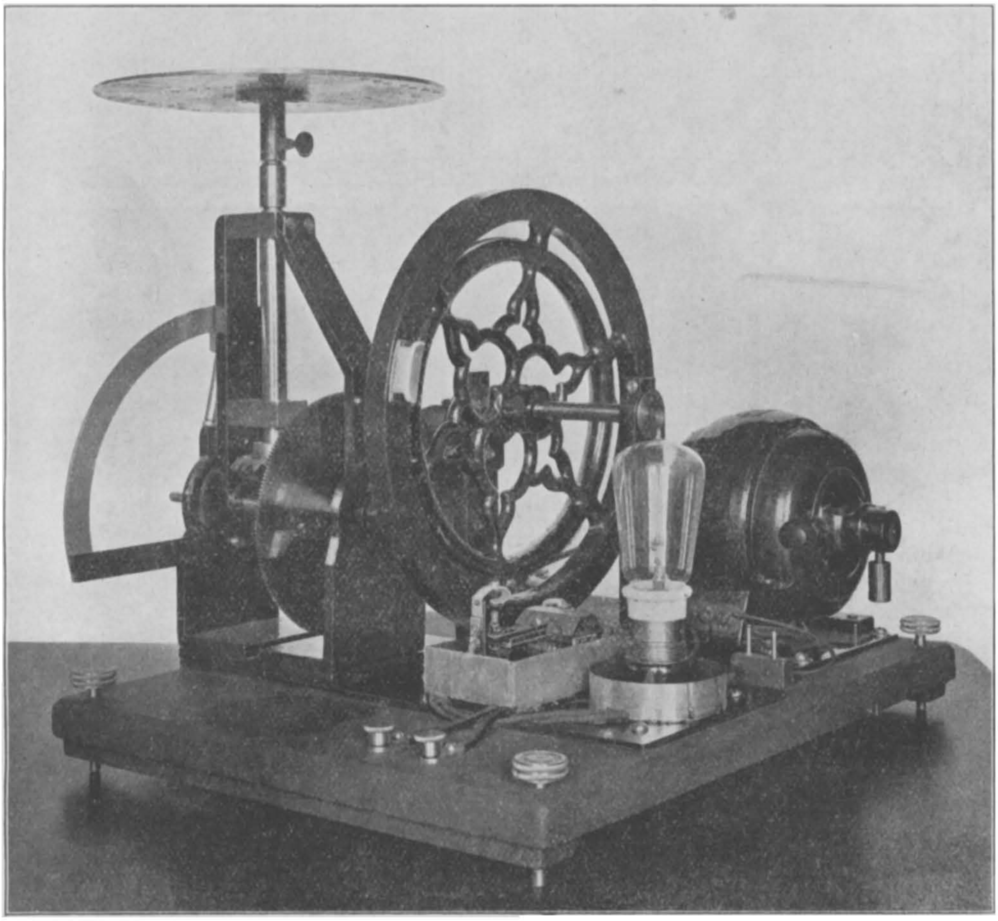

Fig. 3. Backview of the whole clinostat.

minutes must always be the same; so the distance between the time-signals must not vary with a good clinostat.

Now the various clinostats were tested in two ways; partly without load, partly with an excentric load on the axis. This latter was done, because that very unequal load causes the greatest difficulties in practice, especially when in the dark plants have to be fixed on a clinostat, or when we have to try several times in order to get an exact centering, when meanwhile the plants have already been exposed to the unilateral influence of gravitation for a long time. Fig. 4 shows the results of those experiments.

In I the behaviour of a clinostat of PFEFFER is shown with an excentric load, amounting to 0,26 KG. when calculated on the axis.

31

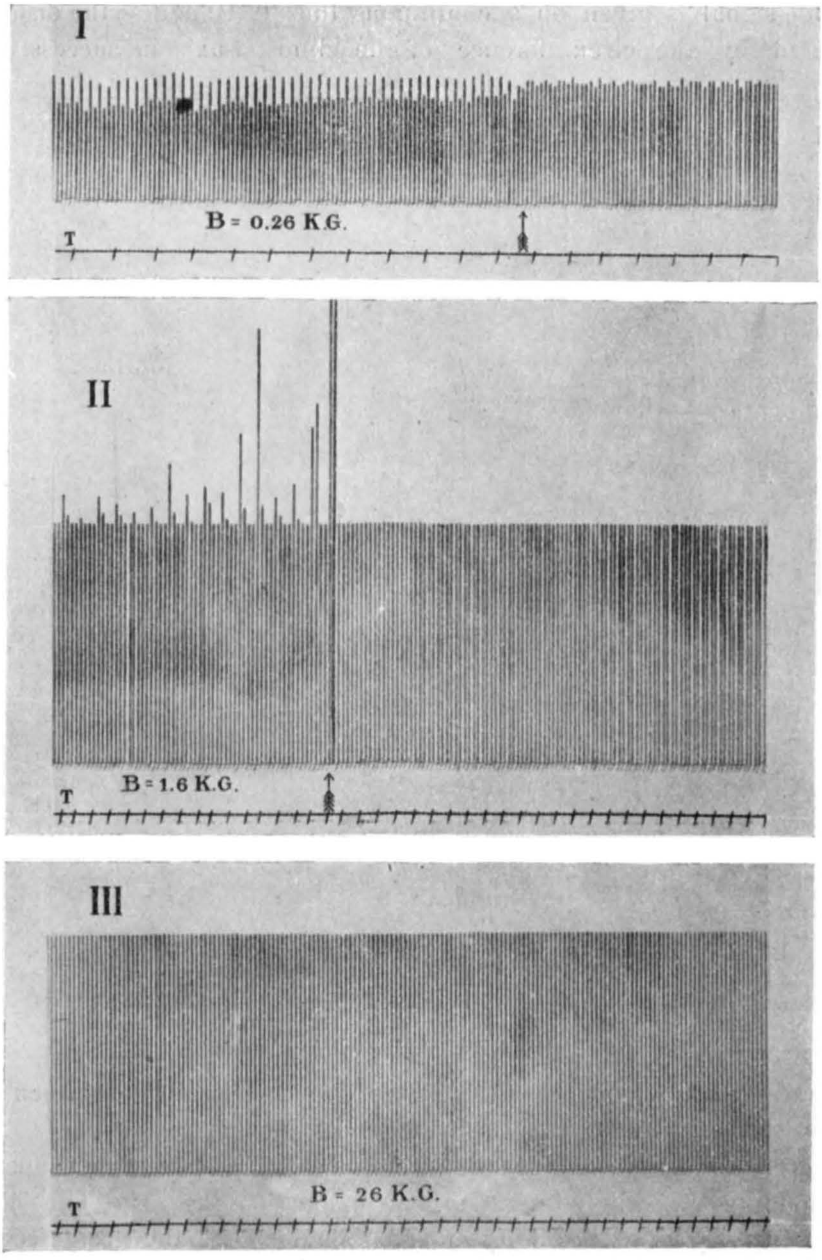

Fig. 4. I. Clinostat of PFEFFER. Records of half rotations. B is the excentric overload converted on the axis. At ↑ this load was removed. II. Clinostat of VAN HARREVELD. Record of 1/4 rotations. B as above. At ↑ this load was increased to 2 KG. at which the clinostat stopped; next the overload was removed. III. Clinostat of DE BOUTER. Record of half rotations. B. excentric overload as above. In all 3 figures T is the time-line, checked every 6 minutes.

It may be noticed how great the difference is between the two halves of the revolution, while this difference disappears beyond the arrow, indicating the moment at which the excentric load is removed.

II refers to the clinostat of VAN HARREVELD; here the excentric load was larger, 1.6 KG., calculated on the axis and there too irregularities appear, which are sometimes very considerable. The arrow indicates the moment at which the excentric load was increased to 2 KG. The clinostat had come to a stop; this happened with a clock-weight of 13 KG. If a heavier weight had been chosen, the movement would of course have continued. After removing every excentric load, the running was perfectly regular, as appears from the rest of the figure.

III shows the working of the clinostat DE BOUTER with an excentric load of 26 KG. calculated on the axis. We see that notwithstanding this, it runs quite regularly, so that the superiority of this clinostat is perfectly clear from the figure.

A contemplation of the time-signals T in the three parts of the figure will necessarily lead to the same conclusion; these time-signals gave a sign after every six minutes.

Summarizing I arrive at the conclusion, that this clinostat is a great improvement on those hitherto used. Now that plant-physiology is developing more and more into an exact science, the old "a peu près" methods will have to be left and therefore care should be taken that the instruments used come up to high requirements of precision.

Utrecht, Botanical Laboratory, December 1922.