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III. *On the Interpretation of Milne Seismograms.*

By C. COLERIDGE FARR, D.Sc.*

[Plate XVI.]

THE question whether a horizontal pendulum Seismograph acts as a clinograph or whether its records must in part be ascribed to horizontal movements of the Earth's surface has received discussion by Milne†, Omori‡, and by others also whose arguments I have not been able to peruse. Both Prof. Milne and Dr. Omori conclude that the tilts represented by the maximum displacement of the boom would indicate earth movements too large to be admissible.

Without attempting to give a complete theory§ of the movement of the boom, or denying that horizontal movements may occur when the inertia weight will act as a steady point, yet from the ordinary elementary theory of forced vibrations|| the equation giving the movement of a vibrating body, whose "free" frequency is $n/2\pi$, under the action of a periodic force $E \cos pt$, is

$$u = \frac{E}{\sqrt{(n^2 - p^2)^2 + k^2 p^2}} \cos (pt - \epsilon). \quad (1)$$

If k , the resistance due to friction, be small compared with the difference of the squares of the frequencies, the resulting vibration has an amplitude

$$u = \frac{E}{n^2 - p^2}, \quad (2)$$

whilst, as is well known, the period of the vibration takes the period of the disturbing cause.

Though an earthquake record is probably due to several terms of the form $E \cos pt$ with different coefficients of decay, yet in many instances I have seen a considerable portion of the record appear to consist of waves of one wave-length, in which case the above simple formula will give at least a general idea of the earth movement corresponding to any diagram; but to obtain it a knowledge of " p " as well as " n " is necessary, for which purpose the tape must be driven sufficiently fast

* Communicated by the Physical Society: read March 13, 1903.

† 'Nature,' vol. lxx. p. 202, and B. A. Report Seismological Committee.

‡ Publications of the Earthquakes Investigation Committee, No. 5, Tokyo, 1901, p. 45, *et seq.*

§ The theory of the horizontal pendulum is discussed at length in *Comptes Rendus des Séances de la Commission Seismique Permanent* 1902, which reached me after this paper was written.

|| Rayleigh, 'Sound,' 1st ed. vol. i. p. 38.

for the period of the forced vibration to be determined, which is not the case with Milne seismographs as at present constructed.

A possibility in these diagrams which appears to have been overlooked is that of interference effects between the forced and free vibrations of the boom. In order to ascertain the effect of periodically loading the pillar, I attached wooden boxes on its east and west sides. These were filled with sawdust. Two chains, fastened together by a rope passing over two pulleys fixed to the ceiling, were hung one over the centre of each box, and the rope was of such a length that the chains just touched the sawdust in the boxes together. By working this arrangement up and down at definite speed, I was able to imitate in a rough way a periodic tilting of the pillar. The total movement of the boom when one chain was removed from its box and the other placed in its proper box was 1.6 mm., *i. e.* the tilt was $\cdot 35''$ whilst the chain was in its box. With this apparatus I imitated in succession waves of periods of 12, 13 ... to 20 seconds, whilst the boom period was 16.5 seconds throughout. I had previously increased the tape speed sufficiently to be able to count the number of vibrations of the boom. Some of the diagrams thus obtained are reproduced (figs. 1 to 4, Plate XVI.). In every case the number of vibrations performed by the boom was exactly the same as the number of motions of the chain. In every case also the amplitude due to periodic displacement was greater than that due to steady loading, though in no case did the simple formula (2) give the observed extent of the swing. The latter is always less than it should be. The discrepancy is probably due to three causes: (1) The imperfect representation of a sine curve with the apparatus. (2) It does not follow (as indeed it is one of the objects of this paper to point out) that because the pillar was tilted $\cdot 35''$ when statically loaded, that it was also tilted that amount when periodically loaded by the same weight—it depends on whether $n^2 - p^2$ as applied to the pillar was $> =$ or < 1 . (3) A certain amount of viscosity exists in the pillar, which prevents it responding promptly to its load.

The diagrams show interference effects well, especially that representing 15 sec. waves. That some of the throbblings so common in earthquake diagrams from the Milne instrument, and called by Professor Milne "Echoes"* are in reality interference effects I have little doubt. The 15 sec. diagram shows a series of lens-shaped throbblings remarkably like a very common feature of a seismogram. The interval

* British Association Reports, p. 227 (1899).

given by Milne of usually from 2 to 6 minutes* between the shock and its echo is exactly that between the beats. On the 15 sec. diagram the interval is about three minutes for a boom period 16.5. With a nearer approach to isochronism the interval would be longer until, if the periods are sufficiently near, the free vibration will have been damped out before opposition in phase can occur. This is evident in the 16 sec., 17 sec., and 18 sec. diagrams.

The object of this paper is to point out that on ordinary elementary theory it is erroneous to derive information regarding the movement of the earth from the measurement of the boom of a Milne seismograph as at present constructed, as we have no knowledge to what extent synchronism may affect the result. To obtain the necessary knowledge the tape must be driven at a higher speed, or it might be obtained in some cases from the interference effects. In cases where there is a near approach to isochronism between the boom period and the wave period, the amplitude of swing depends largely on the damping effect of friction (equation 1), which is entirely ignored at present in this connexion.

LIII. *A Penetrating Radiation from the Earth's Surface.*
By H. LESTER COOKE, M.A., *Demonstrator of Physics,*
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C. T. R. WILSON‡ has examined the rate of discharge of an insulated charged conductor placed inside a closed vessel, the inclosed gas not being exposed to any known ionizing agent. The effect of different gases and varying pressures was studied. He found that the rate of discharge was approximately proportional to the pressure and also to the density of the gas employed. This discharge takes place through the gas, and must be ascribed to a production of ions proportional to the pressure and density of the gas; in other words, to the amount of gaseous matter present.

To account for this there are several explanations possible. The ionization may be due to:—

(1) a radiation or active emanation from the walls of the inclosing vessel;

* British Association Reports, p. 72 (1900).

† Communicated by Prof. Rutherford, F.R.S. A preliminary account of these experiments was given before the American Physical Society, Washington, Dec. 1902. An abstract of the paper was published in the 'Physical Review.' See Rutherford and Cooke, *Phys. Rev.* lxxxiv. p. 183.

‡ C. T. R. Wilson, *Proc. Roy. Soc.* lxviii. p. 151 lxix. p. 277.

FIG. 1.

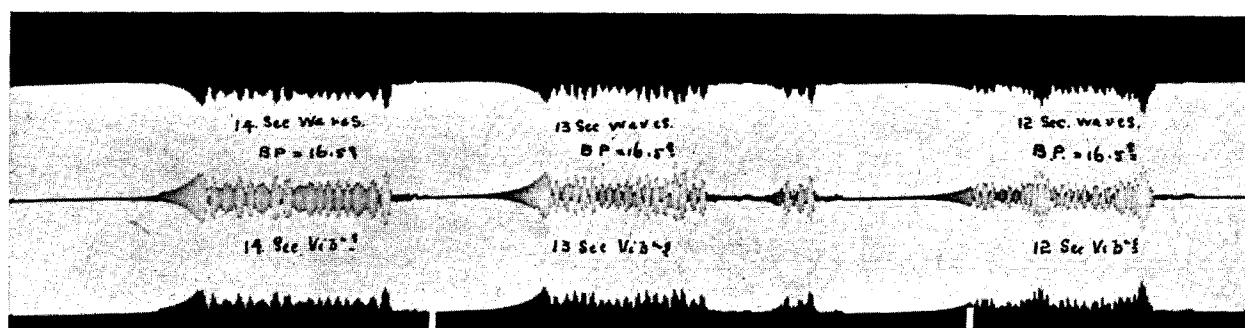


FIG. 2.

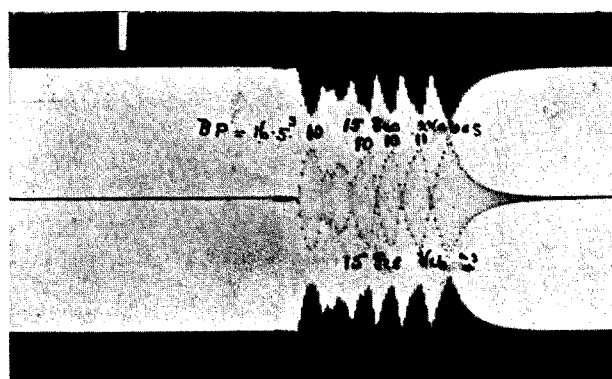


FIG. 3.

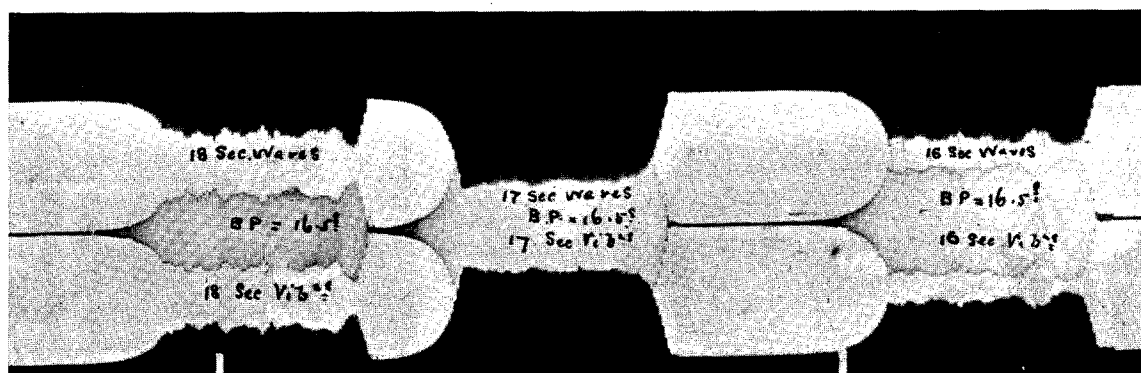


FIG. 4.

