6. *A New Mechanical Low-pass Filter for Seismogram Analyses.*

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1. Introduction: The writer has already studied the behavior of a torsion pendulum as applied as a low-pass filter for seismogram analyses and described some of the interesting results obtained by using this filter for a certain near earthquake.[1)]

As was mentioned previously, the damping of the filter pendulum of the apparatus was effected by oil into which a part of the pendulum is dipped. This arrangement has an inconvenient point, for the temperature of oil must be kept constant by a thermostat in order to get a reliable low-pass filter. The apparatus had some further inconveniences, e.g., the manupulation had to be done in a dark room; the tracing of the original wave forms of mechanically recorded seismograms was difficult on account of their being arc shaped, etc.

In order to improve the apparatus into a more convenient one by eliminating the several points mentioned above, the writer has constructed a new apparatus with an electro-magnetic damper. The design, construction and working of the new apparatus will be described in the following pages.

2. The apparatus: The appearance of this new apparatus may be seen on the photographs of Fig. 1. It is shown schematically in Fig. 2. The pendulum w in Fig. 2 is a brass rod approximately 6 mm in diameter. 4 such pendulums with length of 5 cm, 7 cm, 10 cm and 14 cm are prepared. The moment of inertia of each pendulums can be changed by the aid of two brass cylinders w_1 and w_2 which are slided along the pendulum w.

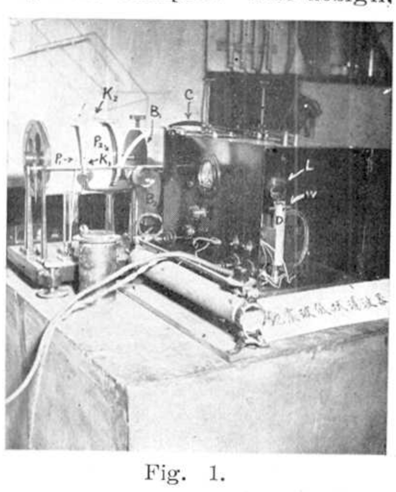

Fig. 1.

1) T. AKIMA, *Bull. Earthq. Res. Inst.*, **26**, (1948), 95, and **27**, (1949), 69.

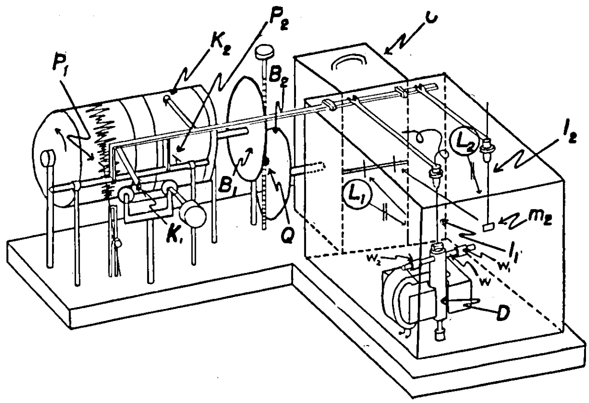

Fig. 2.

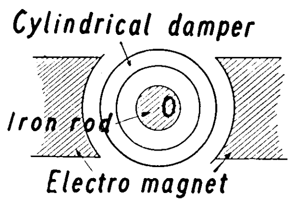

Fig. 3.

The natural period of the pendulum ranged approximately from 5.5 sec to 60 sec.

The damper D is an aluminium cylinder approximately 3 mm thick with an external diameter of 2.5 cm. The horizontal section of the damper at the section of the electro-magnet is shown in Fig. 3, in which 0 is an iron rod and stands vertically along the central axis of the cylindrical damper.

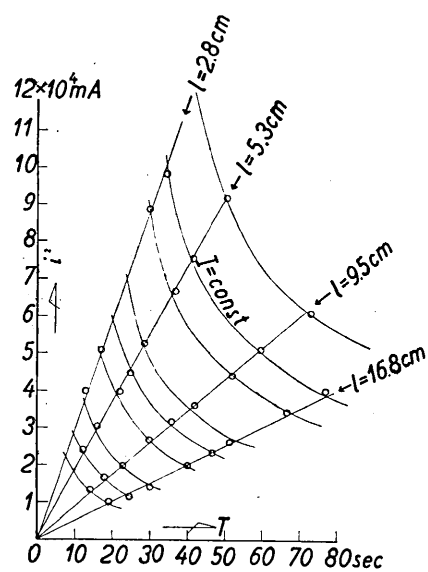

Fig. 4.

The most important point for the pendulum to work as a reliable low-pass filter is that its constant of damping $h\,(=\varepsilon/n)$ must be kept at a constant value of 0.64 for all values of $u\,(=n/p)$. This point must be tested at first of the apparatus. Fig. 4 shows the result of experiments on the relation between the natural period T of the torsion pendulum and the square of the current i which must be fed to the coil of the magnet in order to keep the value of h at 0.64 for all values of T. As T is in our case determined by the length of the suspension wire l, and by the moment of inertia of the torsion pendulum I, the experiments were performed under the condition l=constant and I=constant separately. As is seen in these results, the relation between i^2 and T is linear under the former condition and hyperbolic under the latter condition. These relations agree well with the results of the following theoretical considerations.

In our present case, the resistant constant R and the restitutive constant E of the vibrational system are expressed respectively as follows;

$$R=\frac{C_0\sigma D}{S}\phi^2=C_1 i^2, \qquad E=\frac{\pi\mu r^4}{2l}=\frac{C_2}{2l}$$

where C_0 is a constant determined by the ratio of length and breadth of the section of magnetic flux which pass perpendicularly through the surface of the damper, S the area of the section of magnetic flux given above, ϕ the total magnetic flux, σ and D the electric conductivity and the thickness of the aluminium damper and μ, r and l the rigidity, radius and length of the suspension wire respectively.

From these two equations we get

$$\varepsilon=\frac{R}{2I}=C_1 i^2/2I, \quad n=\sqrt{\frac{E}{I}}=\frac{C_3}{\sqrt{Il}}, \quad T=\frac{2\pi}{n}=C_4\sqrt{Il} \ \ldots\ldots (1),$$

and, therefore,

$$h=\frac{\varepsilon}{n}=\frac{C_1 i^2}{2I}\Big/\frac{C_3}{\sqrt{Il}}=C_5\sqrt{\frac{l}{I}}\,i^2 \ \ldots\ldots (2).$$

Then, under the condition of l=constant,

$$(1)\times(2) \qquad Th=C_6 i^2 \ \ldots\ldots (3),$$

and under the condition of I=constant,

$$(1)/(2) \qquad T/h=C_7/i^2 \ \ldots\ldots (4).$$

The equations (3) and (4) express the relations between T and i^2 which the writer obtained experimentally.

Using the results of Fig. 4, we can easily keep the value of h constant for each value of T by controlling the electric current flowing through the coil of the magnet.

As is seen in equation (3), the gradients of the straight lines in case of l=constant are inversely proportional to the values of h. Using this property, we can draw other straight lines for other values of h starting with the standard straight line experimentally determined for $h=0.64$. Fig. 5 was constructed from the two standard lines determined for two suspension wires with the same length but with different diameters of 1.04 mm and 0.074 mm.

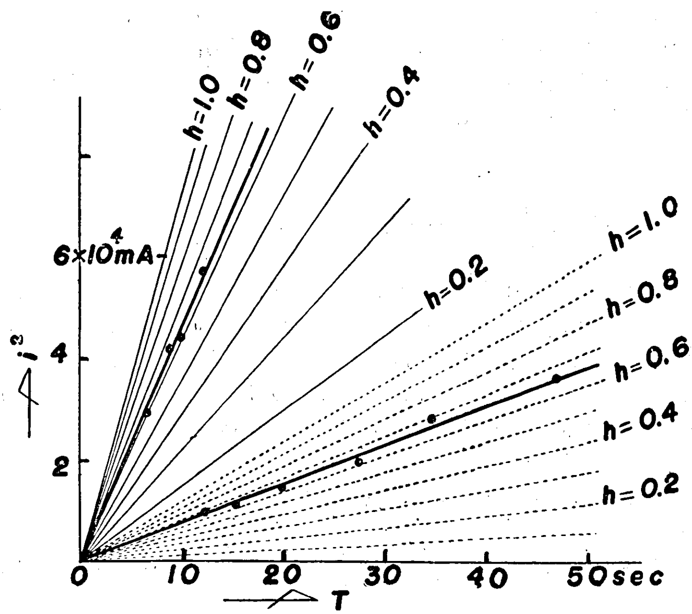

Fig. 5.

In the new apparatus, a rigid rod l_2 is attached vertically beside the torsion pendulum. The light reflected from a small mirror m_2 attached at the lowest end of this rigid rod draws the original wave form in parallel with the filtered wave forms on the oscillograph paper which is moving downward with a velocity of approximately 1 mm/sec in the camera C in Fig. 2. It is easy therefore, to observe time correspondence between the filtered and the original waves, or to investigate the time lag of the filtered waves behind the original waves.

The rotation of the drum on which the original seismograms are wound is transmitted from the recording camera C by means of a small friction roller Q which is placed between the two circular plates B_1 and B_2. The ratio of the rotating velocities can be varied continuously by moving this small roller Q downward or upward. The range of the working natural periods of the filter pendulum can be enlarged to approximately 2.5 sec$\sim$300 sec. The uniformity of the drum rotation was tested by a chronometer and was satisfactorily high for our purpose.

For the tracing of wave forms of mechanically recorded seismograms to be studied, a pen p_1, beside a pen p_2, was added in this apparatus. The length of the arm of the pen p_1 can be changed according to the curvature of the arced shape of seismograms which is to be filtered. Two pens K_1 and K_2 are moved as the pen p_2 and are used for checking the accuracy of the tracing.

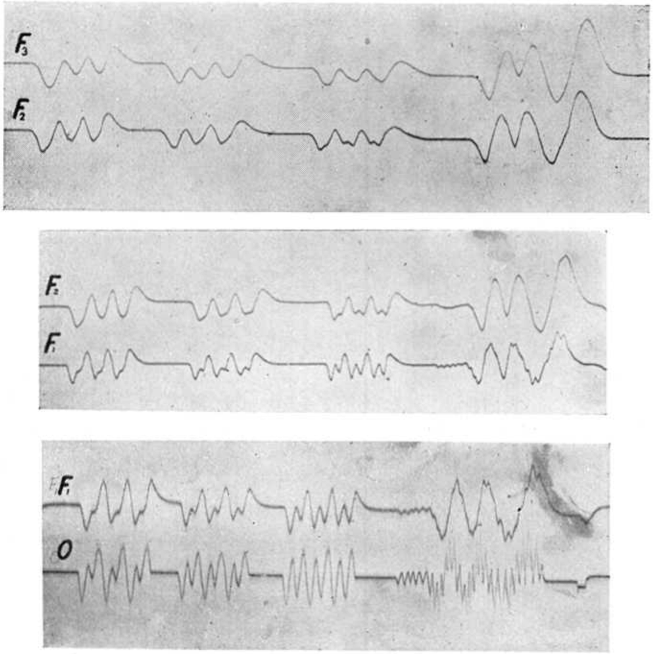

Fig. 6.

3. Some preliminary tests: Several preliminary tests were performed in order to see how the new apparatus works. An example of the results of these tests is shown in Fig. 6. The wave forms marked 0 are the original ones composed of two sinsoidal waves with different periods and amplitudes such as 1) a sine pt + a sine $2pt$, 2) a sine pt + $2a$ sine $2pt$, 3) a sine pt + $4a$ sine $2pt$, and the wave forms marked F_1, F_2, F_3 are the once-, twice- and thrice-filtered ones respectively. These results are quantitatively satisfactory.

The last example shown in this figure is a result of the filteration on an artificial wave form.

An example of the filtered record of an actual seismogram of a near earthquake obtained by using the new apparatus is shown in Fig. 7. In this figure, O is the seismogram of *N-S* component recorded at Titizima in case of an after-shock of the earthquake which took place at the offing of Hukusima Prefecture on Nov. 11, 1938 (Mag. $=$ III, $\Delta = 1110$ km). F_1 and F_2 are the filtered waves once- and twice-filtered respectively. This record shows that a group of long waves appears clearly at the instance marked by an arrow.

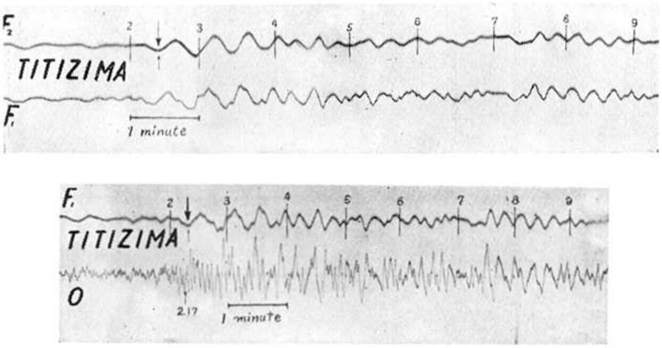

Fig. 7.

In conclusion, the writer express his sincere thanks to Mr. S. Miyamura who gave him many advices in the course of the present study. The expenses for constructing this new apparatus and for the experiments for testing the apparatus were defrayed from the Kagaku-Kenkyu-Hi given by the Ministry of Education.

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6. 電磁制振式新低域濾波器について

地震研究所 秋 間 哲 夫

嘗つて震研彙報 26, 27 號で發表した捩り振子を應用した低域濾波器には，實用上いくつかの缺點があるので，之を今度新しく改良した．本論は，この新裝置が十分滿足すべき機能を有することを述べたものである．
