550.34.8

A METHOD FOR THE CALIBRATION OF SEISMOGRAPHS

by

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Abstract

A seismograph calibrating method involving the use of a known sinusoidal force produced with a coil system and a permanent magnet is described. The system is suitable for the calibration of both mechanical and electrical seismographs over a very wide frequency range. The magnification curves of the seismograph types now employed in Finland are given.

The method

To understand the principle of this method, let us assume that we have a large mass M (the Earth) connected to a small mass m (the seismometer) by an arbitrary system of springs and damping devices. If we apply to the large mass a sinusoidally varying force

$$F = F_0 \sin(\omega t), \qquad (1)$$

it will be set in motion so that its amplitude x is given by $x = \dfrac{F_0}{M\omega^2}$, since the coupling and damping forces between the two masses have a negligible effect on the large mass.

If, in addition, we now apply to the large mass, an equal and opposing force $-F = -F_0 \sin(\omega t)$ and to the smaller mass a proportional force

$$-f = \frac{m}{M} \cdot -F, \qquad (2)$$

the effect of these two forces is equivalent to subjecting the whole system to an acceleration $a = \frac{f}{m} = \frac{F}{M}$, which does not change the relative motion inside the system. However, the forces acting on the large mass will now cancel out and it remains at rest while the smaller mass moves relative to it under the influence of $-f$ and the coupling and damping forces. The result is that the relative motion between the masses that was caused by the large mass moving as a result of (1) can be exactly duplicated by applying the force (2) to the smaller mass alone.

In practice, the record written by a seismograph is a simple function of the relative motion between the seismometer mass and the earth, while its relation to the absolute motion of the earth is generally complicated and must be determined either analytically or by way of experiments. The latter relation is usually given as the magnification curve of the seismograph in response to assumed sinusoidal motions of the earth, and by the above reasoning we arrive at a simple method for its determination. To obtain the magnification of a seismograph at a given angular velocity ω, the corresponding absolute motion of the earth can be simulated by the force (2) applied to the seismometer mass, whereupon the magnification is given by $V = \frac{X}{x} = \frac{X \cdot M\omega^2}{F_0} = \frac{X \cdot m\omega^2}{f_0}$ where X is the trace amplitude.

The moving mass of the seismometer is thus the only constant that need be determined for the calibration.

The calibration equipment

A suitable way of producing the required force is to attach a small permanent magnet to the seismometer mass, place it inside a coaxial coil system and pass an alternating current through the coil. The system is geometrically similar to a Helmholtz coil but as the directions of the currents in the two coils are opposite, a relatively constant axial magnetic field gradient exists within the coil system. The coils used had a radius of about 8 cm and a resistance of 900 ohms. A cylindrical piece of Ferroxdure about 2 cm long was cemented to the end of a brass rod attached to the seismometer mass. The system was calibrated with an analytical balance by passing direct current through the coils, the result obtained being 172 ± 5 dynes/mA. The alternating current was supplied by an electronic signal generator obtained from Servomex Ltd., England, which produced a sinusoidal wave form with a period adjustable from 0.002 seconds to 2 000 seconds. The maximum current output of the generator was 5 mA, which was found sufficient even for the calibration of the 700 kg Mainka instruments at the Helsinki station. For more sensitive instruments, currents down to 25 μA were used.

The damping of the seismograph can easily be studied with square waves produced by the signal generator or a simple circuit, and as the effect of the small calibrating magnet on any seismograph with a mass of the order of one kilogram or more is negligible, the system can be left permanently attached to a seismometer, providing a convenient means for its checking.

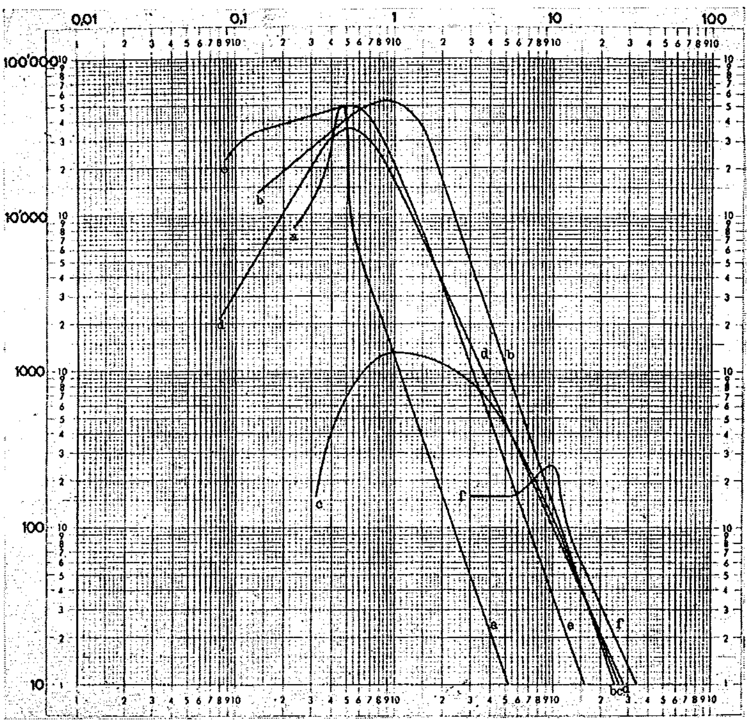

Fig. 1.					
	a—a	Nurmia	Z		10 kg
	a—b	ditto	Z		96 kg
	c—c	ditto	Horiz.		10 kg
	d—d	ditto	»	short-per.	12 kg
	e—e	Benioff	Z		100 kg
	f—f	Mainka	Horiz.		730 kg

The reults

The method described above was used to calibrate all types of instruments now in use in Finland. The results are given in Fig. 1 plotted in a log-log coordinate system.

Acknowledgement: The financial support received from the *Sohlberg's Delegation* to M. KARRAS for this work is gratefully acknowledged.