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A METHOD FOR SELECTING A SEISMOMETER-GALVANOMETER COMBINATION HAVING THE REQUIRED RESPONSE CURVE

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Abstract

One elementary but practical way to select the most suitable system embodying both seismometer and galvanometer having the given response curve is explained. Chakrabarty's magnification equation is divided into two parts, seismometer and galvanometer equations. With the aid of an electronic computer, the families of the two curves with different constants are calculated. Two curves, one from each of the curve families, are then selected and drawn on transparent semilogarithmic paper, and the relative response curve is obtained by adding the two curves graphically point by point. Depending on which of the curves have been selected and at what point on the period axis they have been drawn the instrument constants and the periods of the selected seismometer and galvanometer are obtained.

The initial state of the problem is that for some research work a response curve of a certain form is needed and that a variety of seismometers and galvanometers are available. The present paper is an attempt to clarify how to choose the seismometer and galvanometer so that together they will give the best approximate magnification curve for the research projected.

Using the theory for electromagnetic seismograph and following Chakrabarty's formula for magnification equation we can write:

$$\frac{M\omega_s}{2l_0\sigma_g} = \omega_0\, F(\omega_0)\, F_g(p\omega_0) \tag{1}$$

where

$$F(z) = \left[\left(1 + \frac{u^2}{z^2}\right)\left\{\left(z^2 - 1 + \frac{2kuz^2}{u^2 + z^2}\right)^2 + \left(\frac{2kz^3}{u^2 + z^2}\right)^2\right\}\right]^{-1/2} \tag{2}$$

M = Magnification
ε_s = Damping constant of seismometer
ε_g = Damping constant of galvanometer
ω_s = Angular velocity of seismometer
ω_g = Angular velocity of galvanometer
ω_e = Angular velocity of earth particle

$$\omega_0 = \frac{\omega_s}{\omega_e}$$

$$p = \frac{\omega_g}{\omega_s}$$

$$k_s = \frac{\varepsilon_s}{\omega_s}$$

$$k_g = \frac{\varepsilon_g}{\omega_g}$$

$$u = \frac{L_s\omega_s}{R + S}$$

$$u_g = \frac{L_g\omega_g}{r + S}$$

L = Inductance
$R + S$ = Seismometer circuit resistance
$r + S$ = Galvanometer circuit resistance

For our purpose we write the relative magnification equation in the following formula:

$$M_{\text{RELAT.}} = \frac{F(\omega_0)\, F_g(p\omega_0)}{\omega_e} \tag{3}$$

Combining equations (2) and (3), we obtain

$$_{\text{RELAT.}} = \frac{\omega_e^3}{\sqrt{(\omega_s^2-\omega_e^2)^2[\omega_e^2L_s^2+(R+S)^2]+4\varepsilon_s(R+S)\omega_e^2[L_s(\omega_s^2-\omega_e^2)+\varepsilon_s(R+S)]}\,\sqrt{(\omega_g^2-\omega_e^2)^2}} \tag{4}$$

Equation (3) is the well-known magnification given by Chakrabarty, and it gives the relative magnification of an electromagnetic seismograph at a given earth period.

Because the seismometer output voltage is proportional to the velocity of the seismometer mass it is best to divide equation (4) so that one part of it gives the mass velocity and the other, as we shall see later, the galvanometer sensitivity curve. On dividing, we obtain equations (5) and (6).

$$V_s = \frac{\omega_e^3}{\sqrt{(\omega_s^2-\omega_e^2)^2[\omega_e^2 L_s^2+(R+S)^2]+4\varepsilon_s(R+S)\omega_e^2[L_s(\omega_s^2-\omega_e^2)+\varepsilon_s(R+S)]}} \tag{5}$$

$$S_g = \frac{1}{\sqrt{(\omega_g^2-\omega_e^2)^2+4\varepsilon_g^2\omega_e^2}} \tag{6}$$

With the aid of an electronic computer we can now calculate a family of such curves for different $\varepsilon, L, (R+S)$ values and for the ω_s, ω_g values, for instance $\frac{2\pi}{1}$ and $\frac{2\pi}{0.75}$. For ω_s and ω_g we can give arbitrary values, because the shapes of the two curves do not change when ω_s and ω_g have different values.

In Fig. 1 a family of galvanometer curves is shown. The curves tell us how the recorded amplitudes vary when a constant current flows through the galvanometer coil at different periods. Equation (5) and the left part of Fig. 1 show how the maximum of the seismometer mass-velocity varies when the earth under the seismometer frame is moving continuously like a sine-wave at different periods.

Mass velocity curves:

$L_s = 0$	1.	$\omega_s = 6.283185$	$\varepsilon_s = 1.08699$	$v_s = 1:1.74$
	2.	$\omega_s = 6.283185$	$\varepsilon_s = 3.142000$	$v_s = 1:6$
	3.	$\omega_s = 6.283185$	$\varepsilon_s = 3.605000$	$v_s = 1:9$
	4.	$\omega_s = 6.283185$	$\varepsilon_s = 4.17000$	$v_s = 1:17$
$L_s = 6H$	1.	$\omega_s = 6.283185$	$\varepsilon_s = 3.14200$	$v_s = 1:6$
	2.	$\omega_s = 6.283185$	$\varepsilon_s = 3.605000$	$v_s = 1:9$
	3.	$\omega_s = 6.283185$	$\varepsilon_s = 4.616000$	$v_s = 1:30$

Galvanometer curves:

$L_g = 0$	1.	$\omega_g = 8.377757$	$\varepsilon_g = \frac{1}{2}\omega_g = 4.18878$	$v_g = 6.13$
	2.	$\omega_g = 8.377757$	$\varepsilon_g = \omega_g = 8.37757$	$v_g = \infty$
	3.	$\omega_g = 8.377757$	$\varepsilon_g = 2\omega_g = 16.7551$	$v_g = \infty$
	4.	$\omega_g = 8.377757$	$\varepsilon_g = 6\omega_g = 50.2654$	$v_g = \infty$

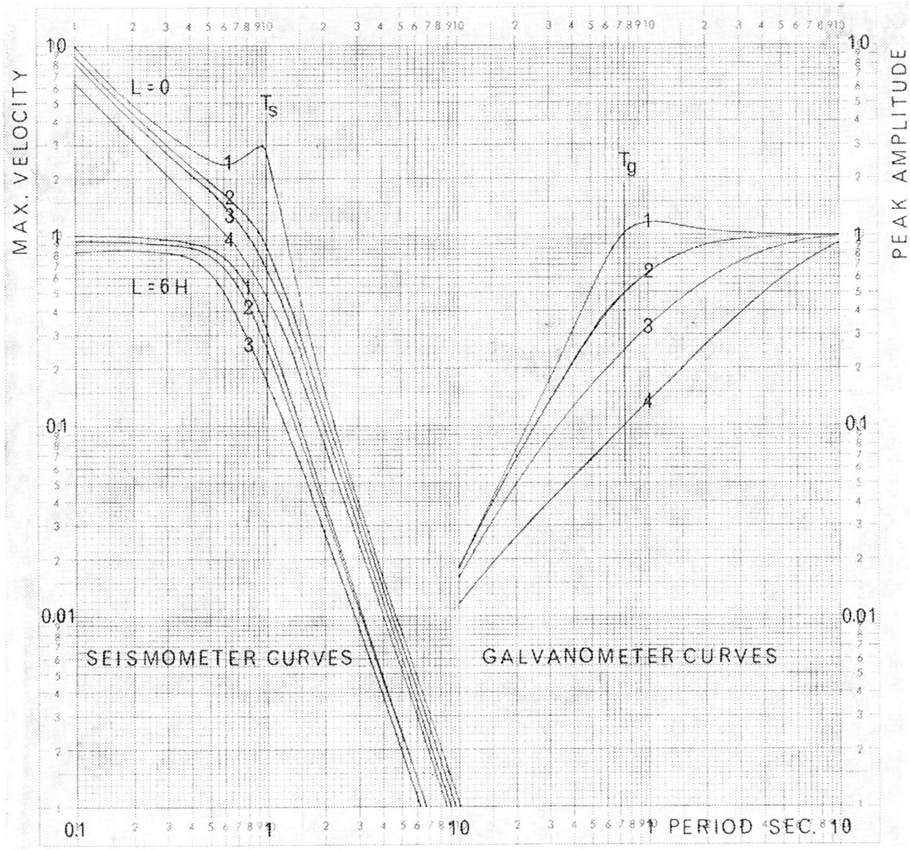

Fig. 1. A family of seismometer mass velocity and galvanometer curves.

After the magnifications have been calculated with different period and constant values, we can start to form the final response curve. First we draw one of the seismometer mass velocity curves on a sheet of transparent semilogarithmic paper so that the line T_s (in Fig. 1) coincides with the period value that we suppose our seismometer will have. Then we select the most suitable galvanometer curve and draw it on the same sheet again so that the line T_g coincides with the best-fitting period value. Now we can add the two curves, using a divider point by point and the resulting curve will be the relative magnification curve. Fig. 2.

If the form of this response curve is not exactly what was wanted, the procedure has to be repeated until the final curve is good enough. It does not take long before one can see how the two curves have to be selected in order to achieve the predetermined shape.

Example: Let us suppose that we have a seismometer and a group of galvanometers with instrument constants as follows:

$$
\begin{aligned}
T_s &= 1-5 \text{ sec (adjustable)} \\
\varepsilon_s &= 0-\omega_s \\
L_s &= 0 \\
(R+S) &= 120\ \Omega \text{ (approximately)} \\
T_g &= 1-30 \text{ sec (group of galvos)} \\
\varepsilon_g &= 0-6\ \omega_g \\
L_g &= 0
\end{aligned}
$$

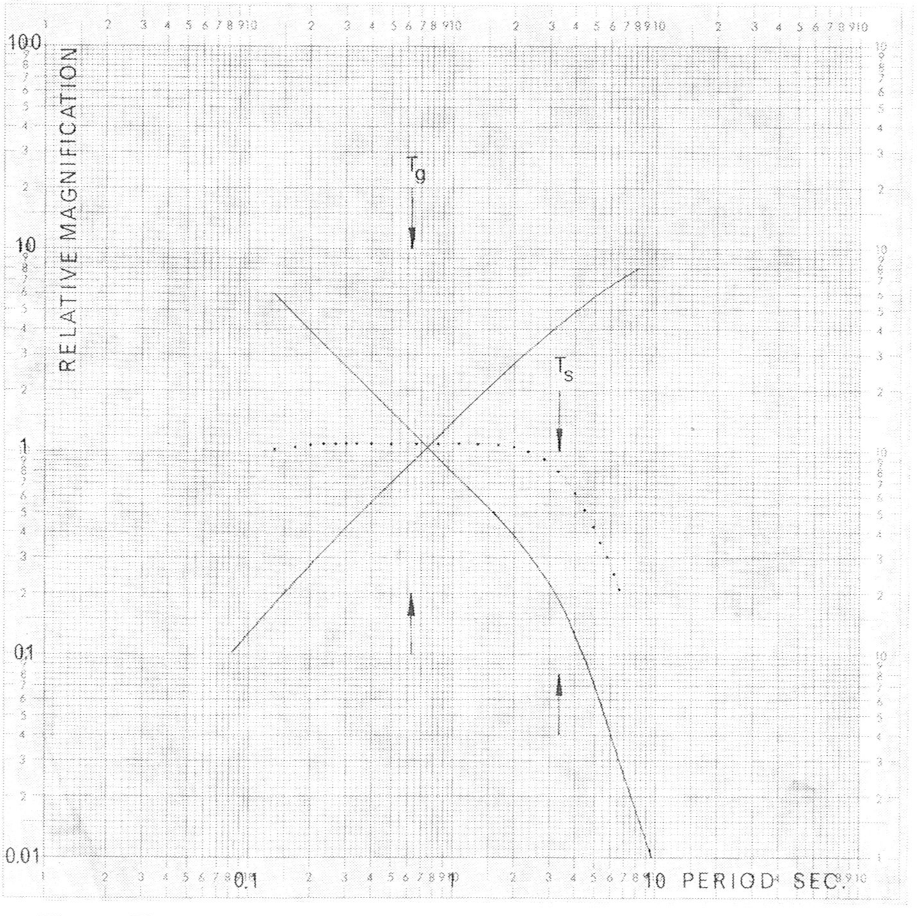

Fig. 2. The curves for max. velocity, galvanometer sensitivity and relative magnification (dots).

and that we need a magnification curve as flat as possible between periods 0.2—2 sec. Fig. 2 shows the addition and selection of the curves. The figure shows that one suitable combination will be as follows:

$$
\begin{aligned}
T_s &= 3.35 \text{ sec} \\
\varepsilon_s &= 2.085 \\
v_s &= 1:17 \\
L_s &= 0 \\
(R+S) &= 120\ \Omega \\
T_g &= 0.63 \text{ sec} \\
\varepsilon_g &= 6\,\omega_g \\
L_g &= 0.
\end{aligned}
$$

REFERENCE

Chakrabarty, S. K., G. C. Choudhury and S. N. Roy Choudhury 1964: Magnification curves of electromagnetic seismograph. *Bull. Seism. Soc. Amer.*, **54**, p. 1462.