A Long-Period Seismograph System*

FRANK PRESS, MAURICE EWING, AND FRANCIS LEHNER

Abstract—A matched three-component seismograph system operating with pendulum period of 30 sec and galvanometer period of 90 sec is described. As a result of increased sensitivity for periods greater than 20 sec, seismograms from these instruments contain information not previously available.

Introduction—The advantages of a seismograph system consisting of three matched components are well known. Instruments incorporating this feature were built by Galitzin, *Benioff* [1955], and Hiller. In this paper we describe a system of longer period than any of these, designed to improve the recording of seismic body and surface waves of longer period.

It is desirable to limit the response of such a system in the short-period range. This would minimize the response to microseisms (which limit the usable sensitivity of any seismograph system) and bring out long-period phases which are obscured by shorter period vibrations on standard seismograms. The major problem was that of constructing a stable vertical pendulum with a period of about 30 sec. A solution was found by using the zero-length spring principle of *La Coste* [1934] and the recently developed isoelastic spring materials, and by compensating for the buoyant effect of atmospheric pressure fluctuations.

Since 1951, a buoyancy compensated vertical seismometer [*Ewing* and *Press*, 1953] with periods of 15 and 90 sec for pendulum and galvanometer, respectively, has been operated at Palisades. The expected advantages of the instrument were quickly realized and, in addition, waves of several types, previously unknown, were recorded. In 1953, the matched horizontal components were added and the expected advantages again were soon realized. During the next few years, additional instruments of this type were installed in Bermuda, Pietermaritzberg, Perth (Western Australia), and Waynesburg (Pennsylvania).

Excellent results having been obtained in all cases, it was decided to make available a standard design of this seismograph system. This design was engineered by Lehner and Griffith, Inc., and is being manufactured by them as the Press-Ewing seismograph system. These instruments have been recording in Pasadena since 1956 with $To = 30$ sec, $Tg = 90$ sec, pendulum and galvanometer being critically damped. They will be operated at a number of stations during the International Geophysical Year.

Description—Figures 1 and 2 are photographs of the vertical and horizontal components, respectively. The glass sphere on the vertical pendulum serves as the buoyancy compensator. The upright is made of Invar for the vertical and of brass for the horizontal components. It is bolted to the pier through clearance holes in the base plate. The transducer is of the moving coil type, with a coil of 5000 turns of 34-gage magnet wire with total resistance 500 ohms. The magnet is made of Alnico V alloy with pole pieces arranged to produce a radial magnetic field of 2000 gauss.

The brass boom is 14¼ inches long and the inertial mass is 15 lb. The pendulum period is adjustable for stable operation in the range 10 to 30 sec. Damping of the pendulum is accomplished by shunting the coil, approximately 3800 ohms being required for critical damping for operation at a pendulum period of 30 sec. Sensitivity is adequate even when operated in a highly overdamped condition. Space is available on the base plate for installing an additional transducer, for example, to drive a second galvanometer or, after suitable amplification, an ink recorder.

All structural elements of the horizontal pendulum have equal coefficients of thermal expansion, the upright and boom being brass, and the suspension wire phosphor bronze. The boom length, inertial mass, transducer, free period, damping, and sensitivity are identical with those of the vertical.

The cover for each instrument is fabricated from sheet aluminum with a plexiglass window. All joints are sealed against draft with felt gaskets.

A Lehner galvanometer with free period 90 sec, coil resistance 500 ohms, critical damping, current sensitivity 10^{-10} amperes per millimeter

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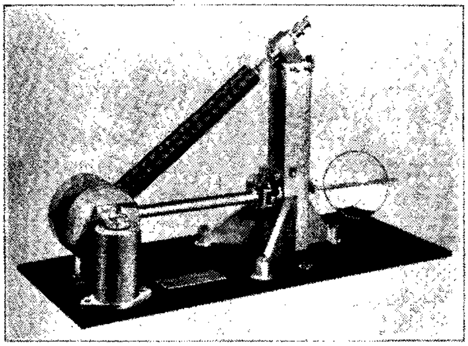

FIG. 1 – The vertical component seismometer

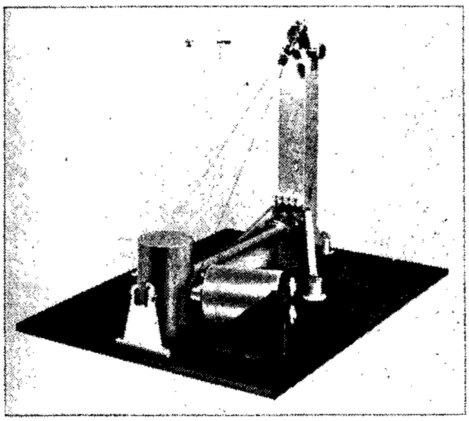

FIG. 2 – The horizontal component seismometer

deflection at one meter is connected to the transducer through a resistive network. The network provides for variation of damping and of sensitivity.

A triple drum recorder is used (Fig. 3), providing perfect alignment between the three seismograms, to facilitate comparisons of phases and determination of orbital motion.

The calibration curve of the instruments operating with pendulum and galvanometer at critical damping is shown in Figure 4. Also shown are curves for other seismographs currently in use. The method of calibration was essentially that of *Murphy* and others [1954].

The peak magnification of 4200 occurs for periods of 25 sec. The response diminishes rapidly for periods less than 25 sec and more gradually for longer periods. Owing to its superior magnification in the period range 20–200 sec, this instrument produces seismograms containing information previously unavailable.

Performance—Although primarily used for

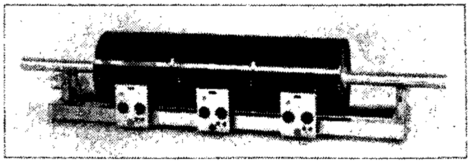

FIG. 3 – The triple component recording drum

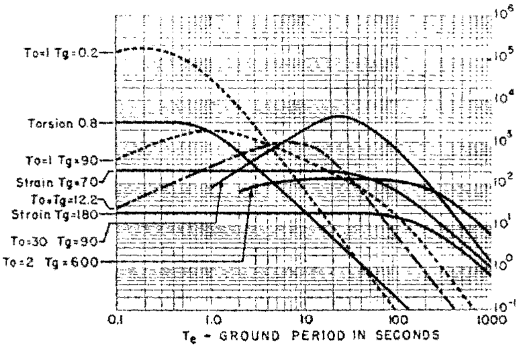

FIG. 4 – Calibration curves of various seismograph systems

research, seismograms from this instrument have been surprisingly useful in routine analysis by providing clear recordings of later body phases, G waves, and the impulsive initiation of surface waves.

The recording of mantle Rayleigh waves from the great Kamchatka earthquake of November 4, 1952, made possible an extension of the dispersion curves for these waves as well as a determination of internal friction in the mantle [*Ewing and Press*, 1954].

Press and *Ewing* [1955] found clear indications of the new phases *Pa* and *Sa* on recordings of these seismographs. *Oliver* and *Ewing* [1957] reported on observations of unusually long-period microseisms.

These examples show how the new instruments have contributed to seismological research by providing increased sensitivity in a period range not covered by other seismographs.

Acknowledgment—That part of this research conducted in Pasadena was supported by a grant from the Alfred P. Sloan Foundation.

REFERENCES

BENIOFF, H., Earthquake seismographs and associated instruments, *Advances in Geophysics*, **2**, 219–275, 1955.

EWING, M., AND F. PRESS, Further study of atmos-

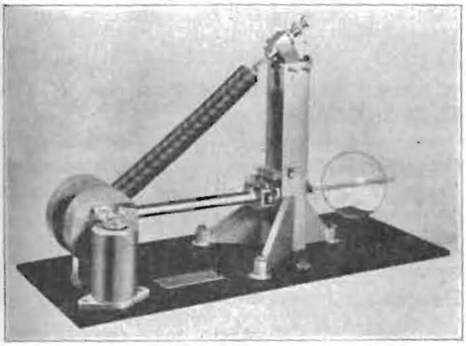

FIG. 1 – The vertical component seismometer

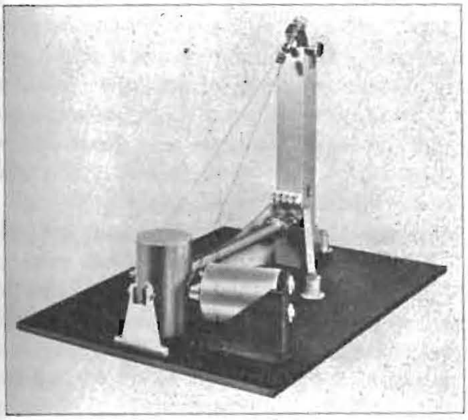

FIG. 2 – The horizontal component seismometer

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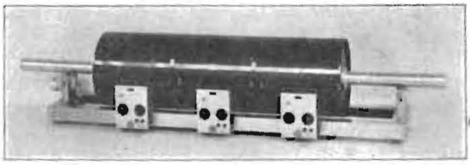
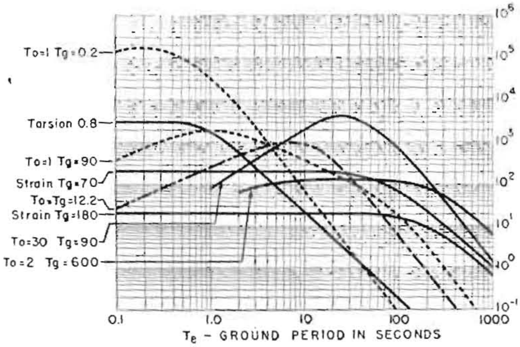


FIG. 3 – The triple component recording drum



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REFERENCES

BENIOFF, H., Earthquake seismographs and associated instruments, *Advances in Geophysics*, **2,** 219–275, 1955.

EWING, M., AND F. PRESS, Further study of atmospheric pressure fluctuations recorded on seismographs, *Trans. Amer. Geophys. Union*, **34**, 95–100, 1953.

EWING, M., AND F. PRESS, Mantle Rayleigh waves from the Kamchatka earthquake of November 4, 1952, *Bul. Seis. Soc. Amer.*, **44**, 471–479, 1954.

LA COSTE, L. J. B., JR., A new type long-period vertical seismograph, *Physics*, **5**, 178–180, 1934.

MURPHY, L. M., R. M. WILSON, L. R. BURGESS, AND T. H. PEARCE. Response curves of an electromagnetic seismograph by sine wave simulator method, *Bul. Seis. Soc. Amer.*, **44**, 7–19, 1954.

OLIVER, J., AND M. EWING. Microseisms in the 11- to 18-second period range, *Bul. Seis. Soc. Amer.*, **47**, 111–128, 1957.

PRESS, F., AND M. EWING. Waves with *Pn* and *Sn* velocity at great distances, *Proc. Nat. Acad. Sci.*, **41**, 24–27, 1955.

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