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49. *A Submarine Seismograph; the First Paper.*

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The Circum-Pacific Seismic Zone lies along the east coast of Japan, so the earthquakes are one-sided with seismic stations established on the arc-shaped Japanese Islands. Subsequently, submarine seismic stations have been requested far off the east coast in the Pacific Ocean, surrounding the epicentres for improving the accuracy of seismic observations generally. Submarine observations may contribute to seismology in many ways such as on propagation velocity of seismic waves on the ocean bottom, on attenuation of seimic waves, on geological structure under the sea, and others. Warning of tsunami may become more reliable than at present if submarine seismographs are set.

The International Union of Geodesy and Geophysics proposed in 1960 international cooperation of seismic observation on the ocean bottom.

In our institute, K. Kanai and T. Tanaka[1] recorded microtremors on the bottom of Ise Bay in Central Japan with a water-proof transducer of 1 second period. Since April 1959, F. Kishinouye started his study on a submarine seismograph and prepared it for trial in 1961[2]. Subsequently, improving many details of the original design, tests of the seismogragh were begun in October, 1962 in the sea near the Marine Biological Station of the University in Misaki, Kanagawa Prefecture, about 60 km SSW of Tokyo.

The Submarine Seismograph

Several methods had been investigated regarding the recording of earthquakes under water before the seismograph was designed. After the studies, the senior investigator concluded that the seismograph must be isolated from the land and surface of the sea, because cables or wires

1) K. KANAI and T. TANAKA, "Self-levelling Vibrograph," *Bull. Earthq. Res. Inst.*, **36** (1958), 359-368.

2) F. KISHINOUYE and Y. KUROKI, "A design of a submarine seismograph." Read on April 25, 1961 at the monthly meeting of our Institute.

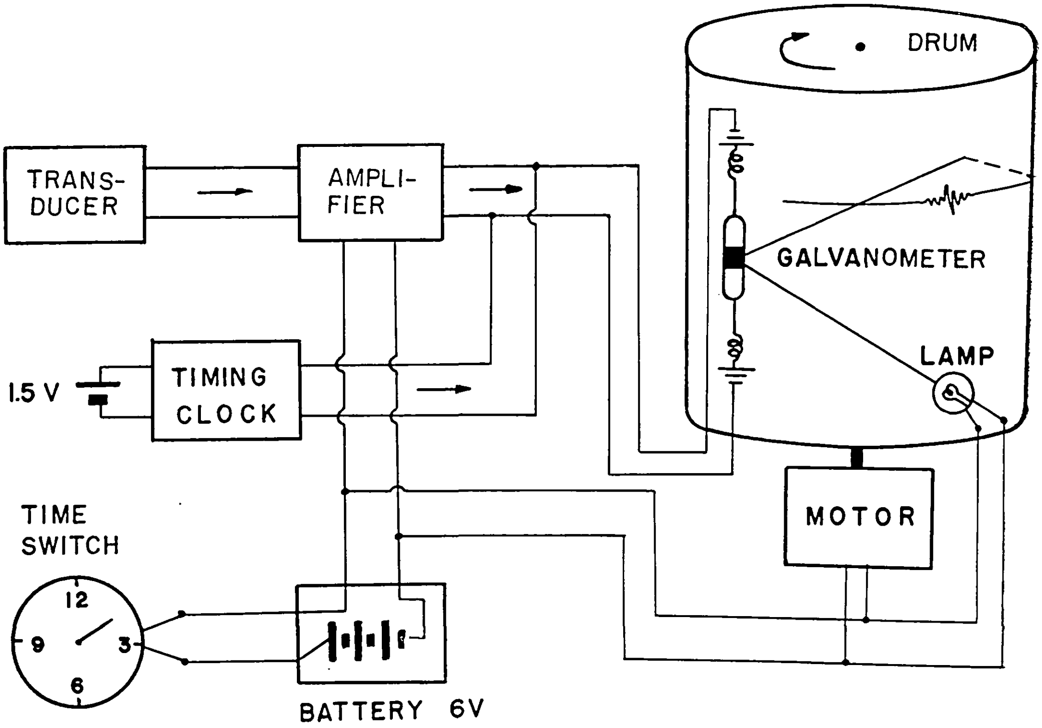

Fig. 1. Submarine Seismograph.

connected from the land or upper strata from the sea bed may disturb the instrument.

Then later the seismograph (Fig. 1) was designed as a system consisting of an iron case containing a transistor amplifier, an electrodynamic transducer of vertical component, a timing clock, an oscillograph, a galvanometer, and a recording photographic apparatus driven by a micro-motor. Attached to and protruding from the case were a float, heavy ballasts to bottom the seismograph, and an apparatus for detaching the ballasts for refloating the seismograph. On the float, an alarming device was attached which gave a warning of the rising of the case upon the surface of the sea when the observation was concluded.

The seismograph case was cylindrical in shape, the diameter of which was 39.5 cm and height 69.0 cm (Figs. 2–7, in Pl. 29). The total weight in air was 250 kg, and 166 kg in water. The self-vibration period of the transducer was 0.1 sec, and that of the galvanometer, 0.01 sec. The transistor amplifier was constructed of CR coupling, and push-pull with

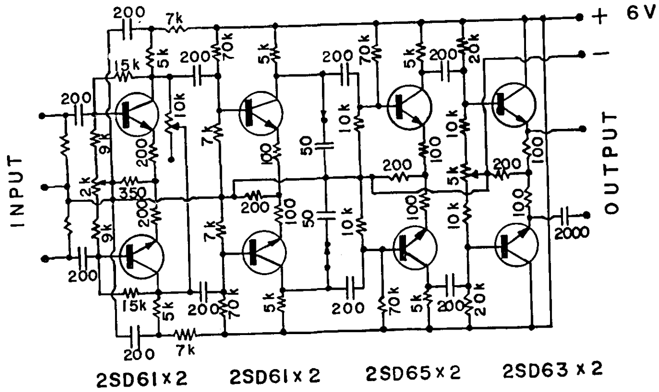

Fig. 8. Amplifier.

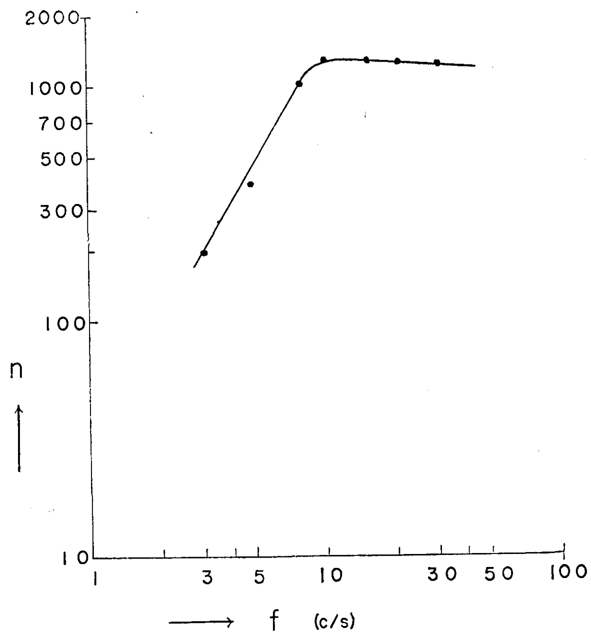

Fig. 9. Magnification curve.

integrating circuit (YTA-1 amplifier, in Fig. 8). The amplification factor was 71 db for 2 c/s, 63 db for 5 c/s, and 57 db for 10 c/s.

The sensitivity of the galvanometer was 15 mm/mA, and length of optical lever to photographic film, 30 cm. The composite amplitude magnification on the film was about 1300 for 10 c/s as shown in Fig. 9. The recording film (24×118 cm) was wound around a transparent plastic cylinder, the film-surface inside.

Timing marks were inscribed on the seismogram every minute and every hour. An electric time-switch was used as a starter for recording after the seismograph case was settled on the sea bed. The switch also clamped the transducer until the recording had begun. When the rotating recording drum proceeded downward and arrived at the end of its rotation axis, the electric supply was broken and all electrical apparatus stopped.

The electric current expended was 53 mA (20 mA through an electric lamp, a micro-motor 20 mA and a transistor amplifier 13 mA), 79 mA for the instant of the timing. In the trial observations, an accumulator was installed in the case so that the submarine observations could continue for about 15 days.

Trial observations

Although the seismograph was designed to endure pressure of sea water at a depth of 500 m, it was set for trial at a depth of 15 m only,

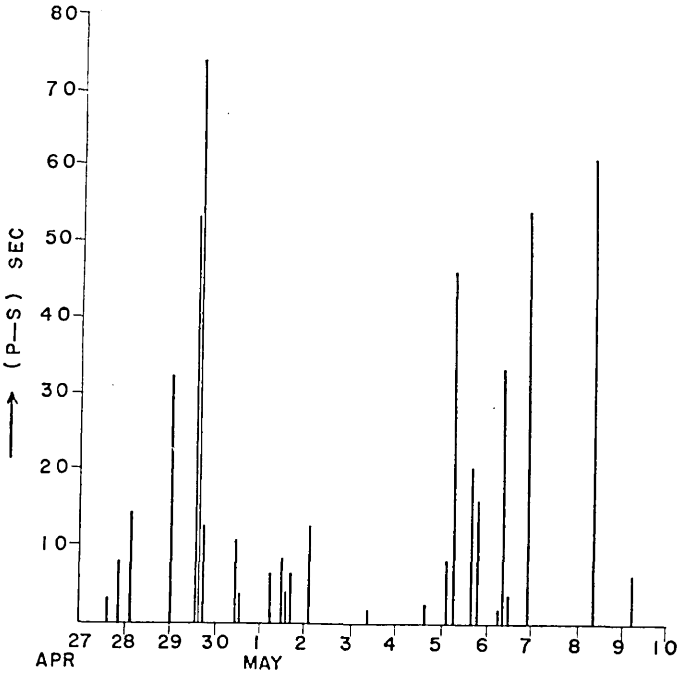

Fig. 11. Submarine observation of earthquakes at Misaki.

as inspection of conditions of the seismograph in sea water is easier in a shallower depth. The conditions studied were as follows: (i) The seismograph case was inclined on the sea bottom. How the instrument was affected by the inclination? (ii) When the case dives down and settles on mud or soft ground and may sink into the ground, can it be raised easily to the observer's position? (iii) How microseisms and short period microtremors are recorded under the sea? (iv) What effects are produced by ships, especially by motorised ships, which disturb the sea producing longitudinal waves or water waves?

To inspect the instrument under the water, a marine camera and diving equipment (aqua-lung) were used.

A continuous trial observation was carried out during the period April 27-May 10, 1963. (Fig. 10.) Although recording on film was not smooth in motion, 26 earthquakes were recorded. The relations between P-S and the number of the earthquakes are shown in Fig. 11. The recorded earthquakes were mostly in close proximity to the seismograph.

After the observations, the wear and tear of recording was overcome by repairing worn driving gear of the drum. Before long, the vibration period of the transducer will be extended to record long period earth motions, and two horizontal component transducers added to the case. The azimuth and inclination of such transducers could be adjusted by an automatic device.

Acknowledgement

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49. 海底地震計 (その1)

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日本附近は地震の多い所であるが，その大多数は震央が海にある．これらの震源の位置を決定するには，海中にも地震計が据えられると観測精度は著しく大きくなる．その他海底における地震波の伝播，海底の地殻構造，津波の発生および伝播などの研究に役に立つ．

この試作した海底地震計は海深約200 m の大陸棚の上を目標とし，海底に据附け上下動を観測し，観測を終えれば自動的に重錘をすて，浮いてくるようにした．今は実験中であるが，海底における地震計の部分について試験的に地震観測をしたので，そこまでの結果についてのべる．

地震計の外側の容器は円筒形で直径 39.5 cm，高さ 69.0cm で，重量は 250kg であるが水中では 166 kg になる．換震器は上下動，周期 0.1 s，検流計は周期 0.01 s，感度 15 mm/mA である．トランジスターをつかつて 2 c/s で約 71 db 増幅するが，記録紙と検流計の距離が 30 cm なので綜合倍率は 10 c/s で約1300 である．記録は 24×118 cm のフィルムの上にとる．全消費電流は 48 mA で，蓄電池の容量が 6V 18Ah であるから約15日間連続観測できる．1963年4月27日から5月10日まで神奈川県三崎にある臨海実験所附近の深さ約 15 m の所で26の地震を記録した，その結果の一部を Fig. 10 に示した．今はその時の記録の機械的の欠点をなおし3成分を記録する海底地震計を試作中である．

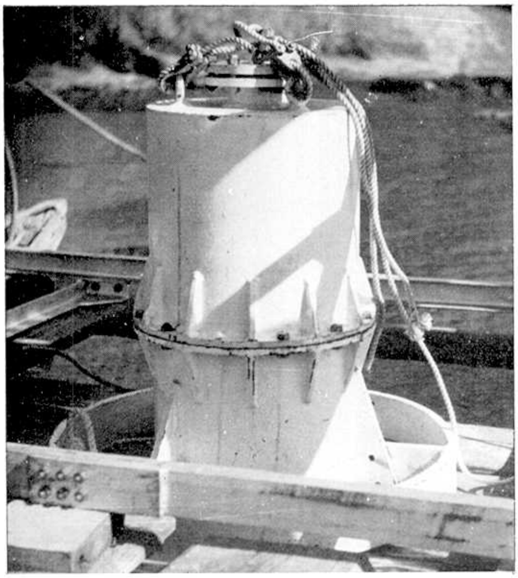

Fig. 2.

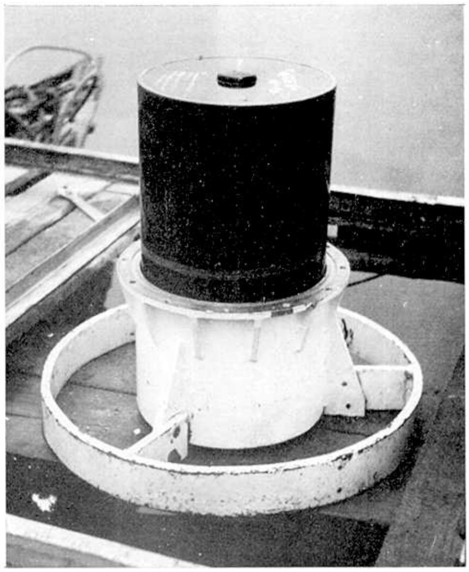

Fig. 3.

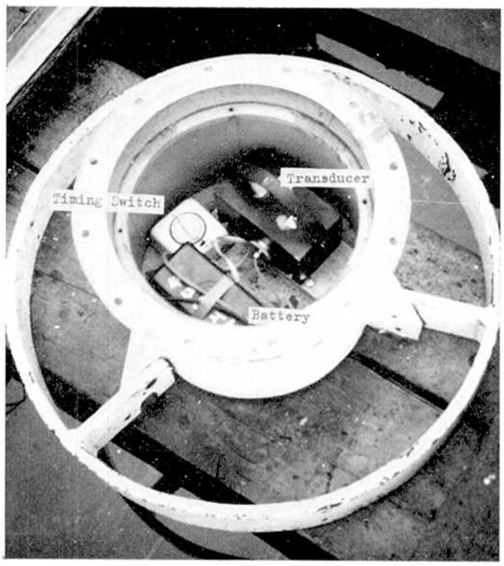

Fig. 4.

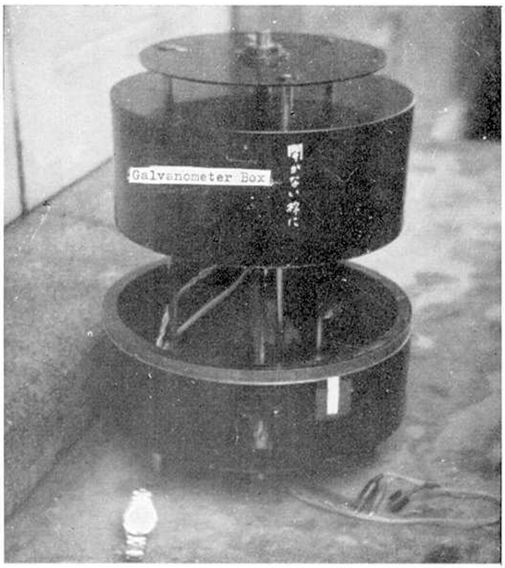

Fig. 5.

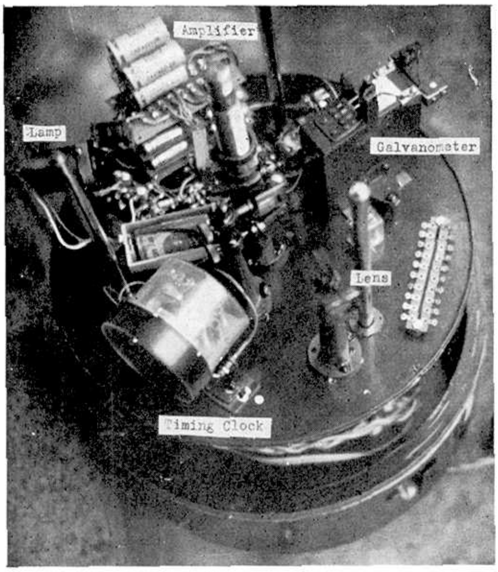

Fig. 6.

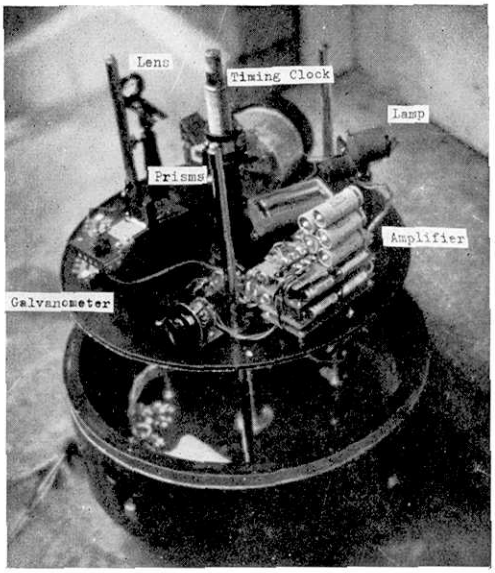

Fig. 7.

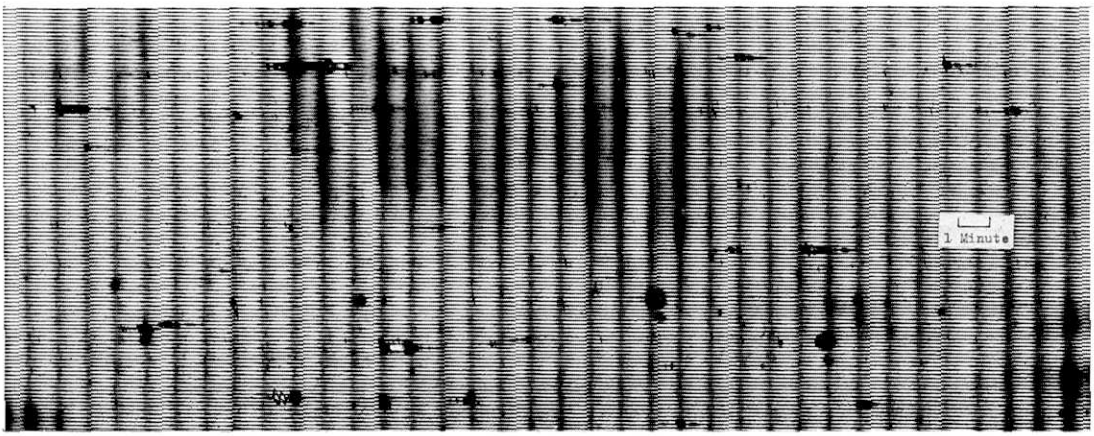

Fig. 10.