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Permanent Ocean-Bottom Seismograph Observation System

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Abstract

The interplate great earthquakes with a magnitude greater than eight, which have caused huge damage over a wide area since the dawn of history in Japan, have occurred under the sea bottom between the Pasific coast and the Japan Trench, Nankai Trough, etc. These earthquakes are considered to be repeated in these areas in future. Consequently, for the prediction of them, it is indispensable to monitor the seismicity in those sea areas. While the Japan Meteorological Agency (JMA) and a number of university laboratories are performing permanent seismic observations at hundreds of stations, the seismographs used are all land-based ones, which results in insufficient accuracy of location and detection capability for small earthquakes in the sea areas.

The anchored buoy ocean-bottom seismograph (OBS) or the pop-up OBS could be used for observation in the sea areas. However, even if the OBSs might catch precursory activities just prior to a big event, they are in some cases of no use in issuing an earthquake warning because nobody is immediately informed of it by them. Under these circumstances, the development of a permanent real-time observation system in the sea areas had been ardently desired.

The JMA had plans to develop the real-time system and to monitor the seismicity in those sea areas. The development of the System was implemented by the Meteorological Research Institute of the JMA as one of the major items of the third Five-Year Plan of the National Program of Earthquake Prediction Research in Japan (1974 - 78). The area off the coast of Tokai District was selected for the area where the System was to be laid.

A number of Japanese seismologists have been afraid that a

great earthquake may occur in the area. Therefore, the Tokai District and the surrounding regions (Shizuoka Prefecture, most of Yamanashi Prefecture, the western part of Kanagawa Prefecture, a part respectively of Nagano, Aichi and Gifu Prefectures) have been designated as "Areas under Intensified Measures against Earthquake Disaster" by the "Large-Scale Earthquake Countermeasures Act" (August 1979).

After its completion, the whole system was transferred to the JMA and has been operated routinely. The JMA, which is responsible for the routine seismic observations and for the issuing an "Earthquake Prediction Information", has plans to lay the same system in the following three areas off Sanriku, from Sagami Bay to off the Boso Peninsula, and off Shikoku. No less than the area off Tokai, these are areas of repeated great earthquakes.

The present paper is a technical report of the development of the System and will be helpful in constructing an improved one when it is required for another sea area.

Chapter 1 is the introduction, in which the position of the System in the National Program is described.

In Chapter 2, the system design and newly developed instruments are described. The System is composed of a land system and a submarine system with a very high reliability (MTBF is estimated to be 100 years per component). The latter system consists of the terminal apparatus set at the far end of a submarine co-axial cable, and three intermediate apparatus linked to the shore by the cable. The former system consists of receiving and repeating apparatus in the shore station (Omaezaki Weather Station), land telephone lines and receiving and processing apparatus in the observation center (Seismological Division, JMA, Tokyo).

The frequency range and the dynamic range of the seismographs are 2 - 20 Hz and 0.01 - 400 μm peak to peak respectively. The frequency range of 0.2 - 20 Hz is also available at the terminal station. A quartz pressure gage attached to the terminal apparatus is a tsunami-meter, with a resolution of nearly 1 mm H_2O and a long term stability better than 0.3 mm H_2O per day.

All signals of the seismographs and the tsunami-meter are transmitted by an FM - FDM with S/N of 72 dB in the sea, and they are demodulated at the shore station, where they are transformed to digital data of 10 bits per component. By the use of the PCM communication method, all the digital data are transmitted to the center via land telephone lines.

Electric power for the submarine system is supplied through the submarine co-axial cable by a DC constant current. It is released from the electrode attached near the terminal apparatus, and sent back to the electrode of the shore earth through the sea-water and the ground.

In Chapter 3 are described the cable route survey and laying work. After elaborate investigation on the topography and geology of the sea bottom, the route was carefully determined so as to avoid cable breaks. The actual laying of the submarine system was successfully carried out in August 1978 by the Kuroshio-Maru, the newest cable ship of the Nippon Telegraph and Telephone Public Corporation. Since the terminal apparatus weighs more than one ton in the water, the newly developed high tensile strength submarine co-axial cable was employed in laying the apparatus. Prior to the laying, a number of experiments including trial laying were carried out.

In Chapter 4 are described the construction of the shore facilities: shore earth work, shore station building including appurtenant facilities and the protection work of the shore cable. For the 35 km segment which lies on seabeds less than 500 m below the surface, a single or double armored cable was used in order to avoid trouble caused by dragnet fishing. Furthermore, for seabeds less than 50 m below the surface, various kinds of trouble due to waves and currents have been experienced. Therefore, the double armored cable guarded by a steel protector was buried in the sea bottom mud.

A half year's test observation was carried out in advance of the transference of the System to the JMA. Chapter 5 includes preliminary reports of some interesting facts observed in the course of the test operation.

There are several earthquakes which would not have been detected and located without the System. Therefore, as has been expected, the details of the seismicity in the area will become clear by use of the data obtained by the System.

One of the interesting facts about the tsunami-meter is that it can work as a kind of long-period vertical seismometer. Seismic waves generated by the earthquake near Etorofu, December 6, 1978 ($M_J = 7.7$), were recorded on the tsunami records. Another interesting fact is that it is available as a level meter to detect crustal movements, because its resolution and stability are good as mentioned above. It may be able to catch the change of the level due to the pre-seismic movement just prior to a break. There has not yet occurred any tsunami in our sea area until now, but the ocean tide level of the open sea is always recorded on the tsunami records. A close correlation is recognized between the tide level recorded by the tsunami-meter and that by the tide gages at shore stations; that is, the amplitudes of the two are almost equal and the phases show systematical lags, as is expected by theory.

The source voltage of the electric power for the submarine system is continuously monitored. In spite of the high stability of the source current, the source voltage shows a slight daily change. It is found that the change is proportional to the time differential of the total force of the terrestrial magnetism. Thus, the observation of the voltage is expected to give new kinds of observational data such as those for geopotential, conductivity and so on. If any precursory change related to geoelectromagnetic phenomena occurred, it might also be detected by observation.

Chapter 6 contains various papers dealing with the development of the System. In the course of the development, meetings of the working groups were frequently held. Important discussions at the meetings also appear in this Chapter.

Chapter 7 comprises reviews, acknowledgements and so on.

The proceedings in the Congress to establish the fundamental policy of research for the JMA are described in the Appendix.