

## **A Direct Recording Pop-up Type Ocean Bottom Seismograph : CDPOBS IIa**

By

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### **Abstract**

The ocean-bottom seismometer CDPOBS IIa is a free-fall, pop-up instrument designed to meet the requirements of seismicity experiments, and is capable of recording three components of seismic data for a maximum of 40 days. Data are directly recorded on a 14 channel open-reel magnetic tape recorder with frequency bandwidth 1~30Hz. Seismic signals from one vertical and two horizontal 4.5Hz geophones mounted on a mechanical gymbal are amplified in three stages (50dB, 70dB and 90dB) and recorded separately. The vertical component is further branched to pass through equalized amplifier to pick up low-frequency component 1~4.5Hz with two gains (50dB and 70 dB), and are separately recorded on two channels. The time reference signal is derived from a quartz crystal oscillator housed in a constant temperature box, and an encoded time signal is recorded in the form of a BCD code. A timer circuit controls the gymbal and geophone clamp mechanism, and emits the anchor-release signal after a pre-determined time. Sensors, electronics and batteries are housed in a spherical pressure vessel with a mid-ring, made of aluminum alloy. After a pre-set time interval or receiving an acoustic command from the ship, either of two gas-pressure piston type releasers makes the pressure vessel ascend. After surfacing, the instrument is found with the aid of radio and flash beacons. The power is supplied by the lithium and nickel-cadmium batteries. Positioning of the OBS can be conducted with an acoustic transponder. A steel anchor with four legs is fastened to the pressure vessel by two releasers.

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## 1. Introduction

We in Japan have suffered severe damage caused by large earthquakes occurring along the oceanic plate boundaries. Ocean bottom seismographs (OBS) can be used for research aiming towards earthquake prediction. The ocean bottom seismograph is ideal for the study of the seismic velocity structure of the oceanic crust and upper mantle, and of micro-earthquake activity along oceanic plate boundaries. These studies will reveal the tectonics at the plate boundary and give useful clues for long-term prediction of earthquakes. In central Japan the seismic stations have been largely distributed on land in order to monitor crustal activity, especially in and around the Tokai area. It is usually difficult to locate earthquakes occurring underneath the ocean with high precision only by means of the land seismograph network. Temporal observation with the OBS arrays will reveal the detail micro-seismic activity around the array as well as station corrections in the focal determination of the land seismic network.

Ocean bottom seismic measurements have been developing since the pioneering work by M.Ewing and A.Vine in 1937. Japan has been one of the leading country in this field (Nagumo et al., 1965, 1968a, 1968b, Shimamura 1969, Shimamura et al., 1970, Hasegawa and Nagumo, 1970, Nagumo et al., 1970, Shimamura and Asada 1970, Asada and Shimamura, 1971, Shimamura and Asada, 1974, Kasahara et al., 1974). In recent years ocean bottom seismic work have been conducted by means of the pop-up type ocean bottom seismograph (Whitmarsh, 1970, Kasahara et al., 1974, Francis et al., 1975, Mataboni et al., 1977, Johnson et al., 1977, Sutton et al., 1977, Langford and Whitmarsh, 1977, McDonald et al., 1977).

The National Research Center for Disaster Prevention started to develop a pop-up type ocean bottom seismograph (CDPOBS IIa) in 1978. Field experiments using this have been undertaken since 1980 around the Suruga and Nankai troughs where a large earthquake is feared in the near future. The following is a detailed description of the CDPOBS IIa.

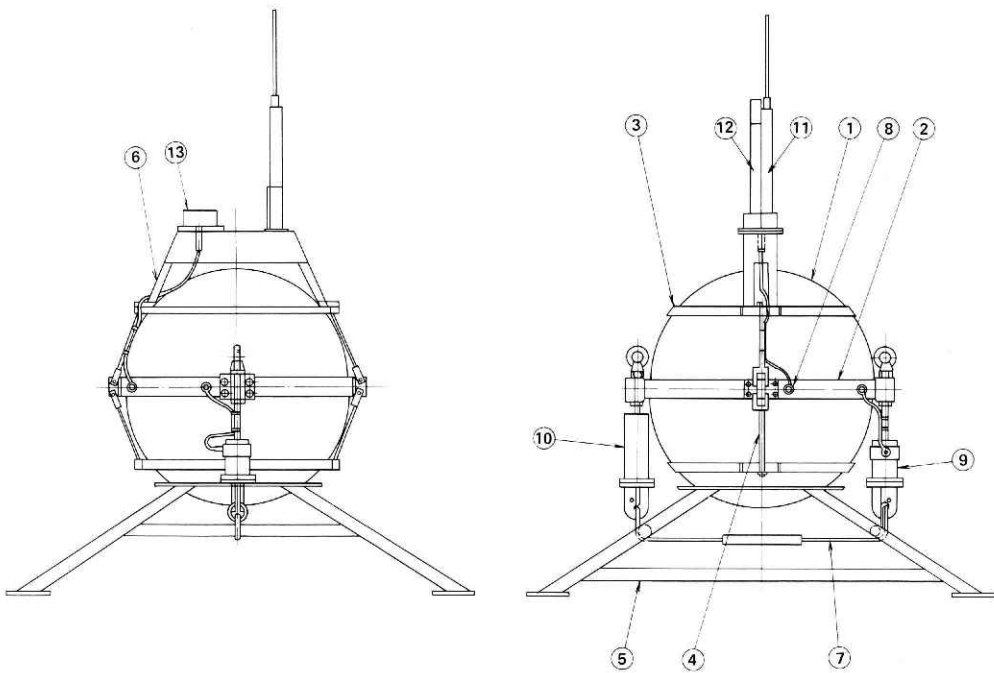
## 2. Design Philosophy

We describe here the operational requirements that prompt the design of our OBS system. The main application for the present OBS is the study of micro-earthquakes to reveal the seismic activity at tectonic boundaries in the ocean at depth of up to 6,000m. First, seismicity studies require a considerable amount of time. This requirement is met by 40 days recording capacity. Seismicity observation also motivated our choice of a continuous recording method. It is not certain that a triggering algorithm can be chosen to assure seismic observation for a whole prescribed span of time considering the various noise conditions on the sea bottom. Reliability is essential in term of both recovery and seismic observation. Thus reliability was a major consideration in design of the system, and rigorous testing of essential parts and of whole system was performed in both the laboratory and the field. As OBS operations are often conducted in rough sea conditions, the system performance test on ship should be carefully chosen and sufficiently simple. It is desirable to make the dynamic range as large as possible to ensure seismic observation of both micro- and larger earthquakes. This requirement was met by introducing

multi-step amplifications of each seismic signal. Bandwidth from 1 up to 30Hz is aimed at in the design of both the OBS and the data play-back recorders. Determination of the OBS's exact position on the sea floor is important both from the standpoint of successful recovery and of seismic measurement accuracy. This requirement is met by measuring the distance between the ship and the OBS or the relative direction of the ship by means of an acoustic system.

### 3. General Description of the Instrument

The CDPOBS IIa is a free fall, pop-up ocean bottom seismometer, capable of recording seismic data for 40 days. Fig. 1 shows an overall view of the CDPOBS IIa, and Fig. 2 the inner part of the pressure vessel. We can see a data recorder with a magnetic tape reel, a direction meter on the top and a clock system in the front face. Sensors, recording electronics and batteries are housed in a pressure vessel with an outer diameter of 75cm. An anchor with four legs is attached to the pressure vessel via two types of releasers (Fig. 3). When either of the releasers works, the pressure vessel is disconnected



- |                    |                 |                  |
|--------------------|-----------------|------------------|
| 1. pressure vessel | 2. mid-ring     | 3. holding ring  |
| 4. holder          | 5. anchor       | 6. platform post |
| 7. wire            | 8. connector    | 9,10. releaser   |
| 11. radio beacon   | 12. flash light | 13. transponder  |

Fig. 1 Outer configuration of the CDPOBS IIa.

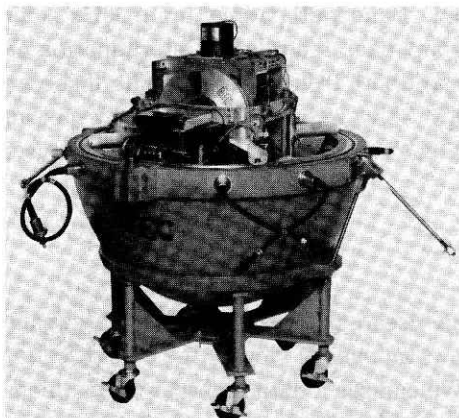


Fig. 2 The OBS electronics, tape recorder and direction finder.

from the anchor, and starts to rise to the sea surface. Radio-beacon and flash light (Ukawa et al., 1984) help to find the OBS after surfacing. Figure 4 is a blockdiagram of the CDPOBS IIa. Signals from the three geophones are amplified in three stages, 50dB, 70dB and 90dB respectively, and transmitted to the long-term recorder. The vertical component alone is further transmitted to a low pass filter and amplified in two stages, 50dB and 70dB. The main clock of the OBS uses a quartz oscillator housed in a constant temperature vessel at 14°C. A clock pulse with an interval of one second is recorded on one channel of the recorder. At the start and at the end of the observation, the internal clock is calibrated by the broadcasted standard time signal using a time correction instrument (Eguchi et al., 1983) through a connector attached onto the mid-ring of the pressure vessel.

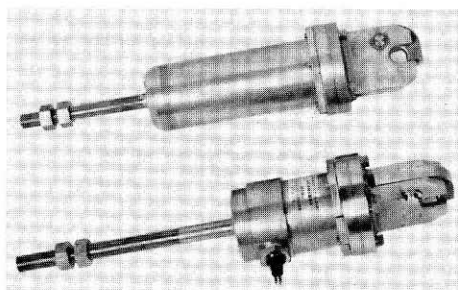


Fig. 3 Two types of releasers. Upper : pre-set timer releaser, lower : acoustic command releaser.

The seismometer is built-in so as to withstand dynamical shocks of up to 50G, making use of a mechanical clamp for the gymbal and an electrical damping clamp for the pendulum. After a pre-ordained interval of time the programed timer circuit frees the electric clamp and the gymbal clamp fix, which makes the OBS start the normal seismic observation. When the OBS receives the release command from the ship, the pendulum clamp is fixed to reduce shocks during the OBS recovery operation.

The direction of the axis of one of two horizontal geophones is measured by the magneto-direction meter, and is recorded on a channel of the recorder in the decimal code.

The release system consists of two mechanical releasers with three types of actuators. One of the releasers is activated by an acoustic command from the ship or the programed timer circuit, and the other by the internal clock of the releaser itself.

The OBS is located after it reaches the bottom either by measuring the relative

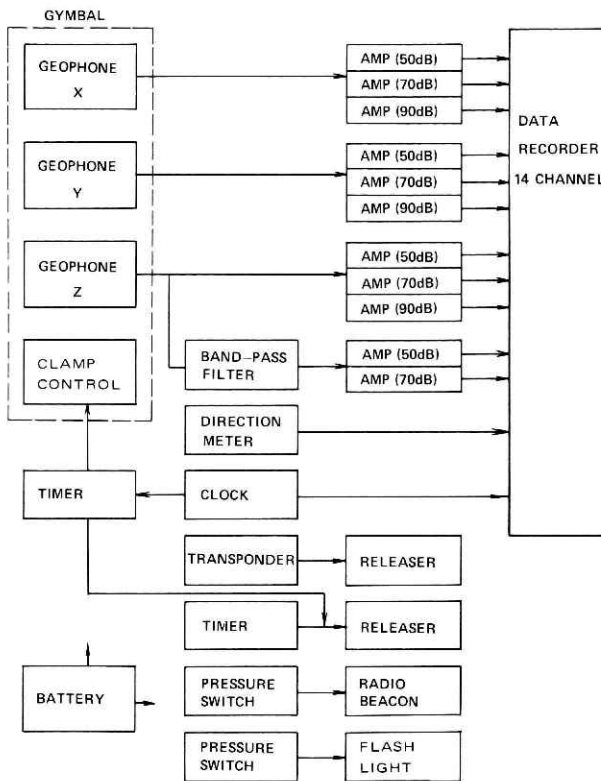


Fig. 4 Block diagram of the CDPOBS IIa.

distances between the ship and the OBS at more than two positions and the ocean depth by a standard precision depth recorder (PDR) or by measuring azimuth and inclination angles of the acoustic recall signal referring to the ship (Eguchi et al., 1984).

Power is supplied from two sources : lithium cells for seismic observation instrument and nickel cadmium batteries for acoustic transponder and releaser parts. The instruments used on the ship deck are a clock calibrator (Eguchi et al., 1983), an acoustic transponder (Eguchi et al., 1984) and the direction finder of the radio wave.

#### 4. Instruments

##### 1) The Pressure Vessel

For the sake of appropriate weight and cost performance we designed pressure vessel to be used almost indefinitely up to a depth of 6,000m. A spherical form of the pressure vessel was chosen because of its extreme buoyancy and the compactness of its total profile. The vessel is made of aluminum alloy (A7178-T6) of 25mm thickness, and consists of three parts : a mid-ring and two hemispheres with an outer diameter of 75cm and inner diameter of 72.5cm. For water proofing two O-rings are placed on two horizontal faces of the midring channel. On the mid-ring, four water-proof connectors are

attached to check electronics housed in the pressure vessel. In the initial stage of the OBS development the strain was measured at 32 representative points on the inner surface of the pressure vessel in a high pressure test tank of the Japan Marine Science

**Table 1** System specifications.

General

Ballasted weight—230kg (in air)  
40kg (in water)  
Non-ballasted buoyancy—25kg  
Descent rate—1ms<sup>-1</sup>  
Ascent rate—1ms<sup>-1</sup>

Pressure Case

Hemisphere O.D. —75cm  
I.D. —72.5cm  
Mid-ring O.D. —85cm  
I.D. —70cm  
Width—5cm  
Material—aluminum  
Type of seal—1 O-ring  
Depth—6,000m

Ballast

Material—steel  
Weight—65kg

Geophone (1 vertical, 2 horizontal)

Natural frequency—4.5Hz  
Sensitivity—2.0V/kine

Clock

Accuracy—10<sup>-6</sup>/month (0°~40°)  
Coding scheme—Serial BCD : one pulse per second

Amplifier

Gain—50dB, 79dB, 90dB  
Noise—less than 1μV

Equalizer

Frequency range—1~4Hz

Tape Recorder

Type—open-reel  
Number of channel—14

Recording speed— $0.15\text{mms}^{-1}$   
Tape duration—1,000hrs  
Frequency response—1 to 30Hz ( $\pm 1.5\text{dB}$ )  
Dynamic range—26dB  
Crosstalk—greater than 40dB  
Wow flutter—less than 1%  
Gain stability—better than 3%

#### Releaser

Mechanism—either of 2 gas-pressure pistons  
Control—either of acoustic or timer command  
Maximum pre-set time—999hrs

#### Batteries

Type —lithium cell, Nickel cadmium cell  
Number—20  
Life —1,000hrs

and Technology Center. The test confirmed that the vessel could be used up to a depth of 6,000m with residual strain of less than 0.2%. Usually, a pressure vessel is tested by measuring dimension, chemical compounds, and mechanical strength of sample pieces and crack density. Anti-corrosion measures consist of coating the surface with paint and inserting a rubber sheet between the pressure vessel and the steel anchor. To prevent the short-circuiting of the electronics in the vessel due to condensation of water vapour, the atmosphere is replaced by  $\text{N}_2$  gas of 1 atm. An acoustic transducer, a radio beacon and a flashing light are attached over the top of the pressure vessel. The balance test of the OBS was performed during both descent and ascent, on the sea bottom and at the sea surface.

## 2) Seismometer

The seismometer is composed of three geophones (one vertical, two horizontal), a mechanical gymbal, amplifiers and electric clamp circuits. The seismometer was originally designed for an on-line ocean bottom seismic station of the Japan Meteorological Agency (MRI, 1980). The natural frequency of the geophone is 4.5Hz with a damping constant  $h$  of about 0.8 and sensitivity of about 2 V/kine. The velocity response is nearly flat above 5Hz. The three geophones are mounted on a mechanical gymbal to keep level the geophone on the ocean floor tilting at an angle of up to 40 degrees. The gymbal is the mechanical type, and is composed of inner and outer rotational mechanisms, whose rotation axes are perpendicular to each other. The maximum rotation angle of the inner and outer mechanisms are  $40^\circ$  and  $60^\circ$  respectively. The OBS may experience dynamic shocks during transportation, deployment and retrieval works. The present OBS is designed to withstand dynamic shocks of up to 50

G. Two kinds of countermeasure are taken against shocks. One is a mechanical clamp which fixes the gymbal by frictional force during transportation or deck works on the sea. After a pre-set time interval a programmed timer frees the frictional gymbal clamp for about 5 minutes, and fixes again after becoming horizontal on the ocean floor. Another type of clamp is an electrical one : a bi-pass resistor to the input side is switched when a relay is closed to reduce the current into the pre-amplifier by about one-tenth.

Signals from the seismometer are amplified in three stages, with gains of 50dB, 70 dB and 90dB, each being variable by  $\pm 10$ dB. Moreover the low frequency component ( 1 ~ 4 ) Hz of the vertical component is passed through a low-pass filter and amplified in two stages, 50dB and 70dB. These signals are recorded separately.

The noise level of the seismometer's electric circuit is less than  $1\mu$ V for a frequency range of 1 ~ 30Hz, and is negligible also for the signal of highest amplification.

The angle of inclination of the gymbal can be read after field observation to infer the tilt angle of the OBS on the ocean floor. The azimuth angle of the OBS is measured with reference to magnetic north and recorded on one channel of the recorder. The direction finder is checked on land with all of the equipment being housed and external instruments attached. It has been ascertained that accuracy is better than 5 degrees.

### 3) Recorder

Our data recorder is designed for 40 days operation with a wide dynamic and frequency range. The direct recording method is chosen because of its larger data-storage capacity and the difficulty in choice of event-triggering algorithms in the condition of many sources of ambient noises caused by natural sources or ships.

The data recorder has 14 channels to record nine short-period seismic signals, two 'long'-period seismic signals, a BCD mode clock signal, the azimuth signal of the OBS, and the OBS control signal. The maximum recording time is about 1,000 hours. The frequency range of the recorder is from 1 to 30Hz with tolerance of  $\pm 1.5$ dB. The tape recorder is of the open reel type with a diameter of 26.7cm. The recording head is composed of two heads each with seven channels ; one head is for odd number channels and the other for even number channels. Tape speed is about 0.15mm/s, with fluctuation being less than of 0.5% for both the OBS and play-back recorder. The signal to noise ratio is better than 30dB in the case of an ordinary play-back speed of 80 times the original.

A difficult problem with the recorder is the mechanical noises caused by the driving motor and tape winding mechanism. To reduce electric current drain as far as possible, we adopted the method of an intermittent tape winding at every three minutes. However, noticeable noise was found to be caused from an abrupt winding motion lasting about 1 second. It was therefore improved changing to a slower winding one lasting about thirty seconds. The azimuthal deviation between different channels of the recorder head is large enough to cause an arrival time reading error of up to some 0.5 second. The azimuth correction signal is, therefore recorded on each channel every 24 hours. It was ascertained by the azimuth test that time differences are steady if the play-back operation is continuously performed. Fig.5 show an example of azimuth changes during about one month's field observation for the channels 2 and 3 relative to the clock channel (14th channel).



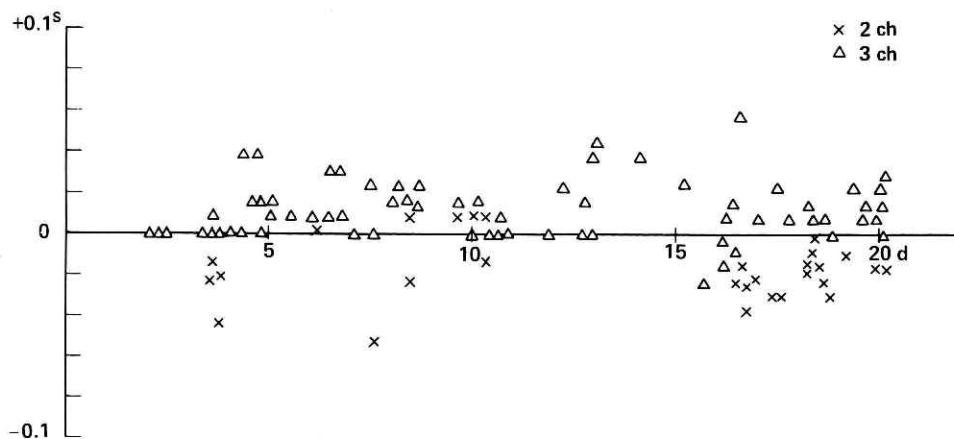


Fig. 5 An example of azimuth changes of two channels of the recorder during about one month of field observation.

#### 4) Clock

The clock is designed to be accurate to at least 0.05 sec. A crystal oscillator is housed in a constant temperature chamber of 14°C to keep frequency stability better than  $0.5 \times 10^{-6}$  for 40 days. The pulse signal is recorded every second. Using the BCD encoding scheme we superimpose on the second pulse the signal of year, month, day, hour, minute and OBS number every minute. The pulse for "00" seconds has a width of 1 second, and that for others 0.5 second. Just before the deployment of the OBS into the ocean, the clock is corrected by the clock corrector (Eguchi *et al.*, 1983) using broadcasted standard time. After recovery of the OBS, the difference between OBS time and the standard time is read and printed using the clock corrector. These time correction operations are performed through the water-proof connector through the mid-ring. Inference of true time at any arbitrary instant during the observation is conducted by the linear interpolation procedure. We also use the clock signal to digitize chosen events in the data play-back procedure. Due to the limited frequency range of the recorder, the clock pulse is deformed to one of differential wave form, which occasionally causes an unstable reading of time in the play-back procedure. Hence, the time pulse is further modulated using a 10Hz carrier signal prior to recording in a later stage of development of the OBS system.

#### 5) Releaser

The pressure vessel is put on a steel anchor with four footpad, and is fastened by stainless steel wire with each end linked with a releaser. A spring is attached in the middle of the wire to give tensional force to a hook on the releaser. The spring is made contact with a bar of the anchor in order to prevent vibration. A schematic diagram of the releaser (internal timer type) is shown in Fig. 6. When in the state of holding, a hook-pin is kept in lower position by means of a small steel ball in a hole of the wall between

a cylinder case for gas ejection and that for the pin. The hook pin stops the hook from rotating. The two hooks of the releasers are pulled by the steel wire. When the gas explodes in the releaser cylinder, the piston is pushed into the lower position with the result that the ball shifts to the hook-pin house. This makes the hook-pin move upwards. The upward force of the hook is caused by torque force due to the spring, and is increased by water pressure. The shift of the hook-pin makes the hook rotate and release the wire from the anchor. If either of the releasers works, the anchor is disconnected and the pressure vessel starts to ascend.

One of the releasers is actuated by the pre-set timer housed in its pressure vessel, and the other is actuated either by a command from the ship or by the timer circuit of the OBS. The releaser was tested in the laboratory, in a pool and in shallow sea.

#### 6) Transponder

An acoustic transducer with a diameter of about 15cm and height of about 10cm is set over the top of the pressure vessel on a platform (Fig.2). The resonant frequency of the transducer is about 10kHz. The transducer receives acoustic signals emitted from the same type of the transducer pulled down from the ship, and sends back response signals. Acoustic signals are made of two carrier frequencies. Duration and alternative frequency of the two carriers make it possible to identify four types of command : OBS number, clamping, locating and release activation. When the signal is identified as that of releasing, the control circuit switches on the releaser and clamp circuits. After switching on the releaser, the OBS sends a "release-activation-end" signal to the ship. When the signal from the ship is identified as the locating command, the control circuit sends back an acoustic signal to the surface. By measuring the time elapsed between the instant of emitting the signal and that of receiving the answer signal from the OBS we can calculate the distance between the OBS and the ship. Measurement of the relative distance of the OBS at more than two positions and water depth enables us to determine the position of the OBS by means of ship position data obtained with ordinary navigation systems such as LORAN or DECCA. Several field tests showed the accuracy of present positioning method to be better than 200m, the error being mostly due to inaccuracy of the ship positioning.

In the later stage, the transponder system was so modified as to measure the angle of the receiving acoustic signal in vertical and horizontal directions by means of pairs of

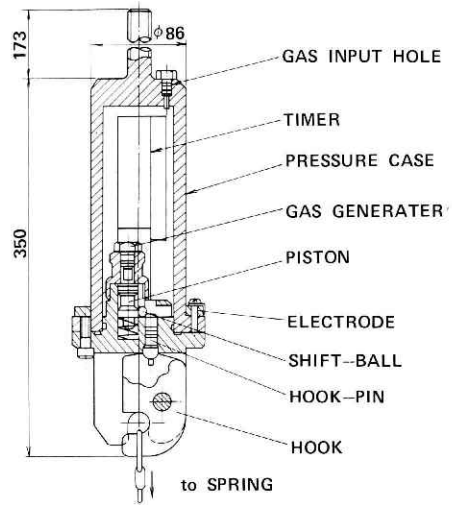


Fig. 6 OBS pre-set timer release mechanism.

resonators, set perpendicular to each other (Eguchi *et al.*, 1984).

#### 7) Flash Light and Radio-beacon

Successful retrieval of the OBS depends on many factors. These are high reliability of the OBS system, especially of the releaser system, accurate positioning, proper weather prediction, prompt finding of OBS on the sea surface and safe retrieval onto the deck.

Positioning OBS during ascent enables us to guess the surfacing point of the OBS relative to the ship. After surfacing radio waves issued from the beacon made by Ocean Applied Research (OAR) or Taiyo Musen (TM) is one of the principal means of finding the OBS. The radio beacon's frequency is about 27MHz (OAR) or 42MHz (TM), and the output power of both is about 0.1W. The radio beacon of TM (Ukawa *et al.*, 1984) has a solid antenna, the transversal resonant frequency of which is about 45Hz far beyond the frequency range of the seismic observation. Moreover the radio wave can be caught within about 20km by our receiver. Each TM beacon contains an individual station code, and the wave is emitted for 30 seconds per minute. The direction of the radio wave is measured using a loop antenna with reference to the head of the ship. Reflected waves caused by structures on the deck sometimes give rise to ghost images, and setting the antenna at the highest position of the mast will reduce these. It is essential to calibrate the radio direction finder in the open sea before the recovery operation. Flash beacon made by OAR or by TM is attached on the top of the OBS for retrieval work at night. The flash light is sent every other second for about 200 hours. The light has proved very powerful means of finding the OBS for night time recovery.

#### 8) Control Timer

The control timer (Fig.1) sends commands of locking and unlocking to the clamp circuit for both the gymbal and geophone. It also sends the command of releasing to one of two releasers. We can set three time,  $T_1$ ,  $T_2$  and  $T_3$  :

$T_1$  : time one hour unit to be elapsed from the start of the timer to the time the gymbal is unlocked ; the gymbal is made free for 15 minutes and is then relocked ; 15 minutes later the geophone clamp is unlocked to start normal seismic observation.

$T_2$  : time (10 hours unit) from the instant of the geophone unlocking to that of the locking before pre-set releasing.

$T_3$  : time (one hour unit) from the geophone locking to the release commanding.

These three times are set before the closing of the pressure vessel. When the OBS receives the acoustic command for releasing, the geophone locking is promptly executed regardless of the times  $T_2$  and  $T_3$ .

#### 9) Batteries

Power for electric instrument is supplied by lithium and nickel cadmium batteries. The lithium batteries are used for the instruments which operate continuously, such as the recorder and the amplifier ; and the nickel-cadmium batteries are for the instruments which operate for only a short time, such as the acoustic transponder and the releaser. The power supply is designed to be mutually independent as far as possible. A total of seven systems of batteries are used ; that is, one for the geophones, one for the recorder,

one for the direction finder, one for the timer, clock and control circuit, one for the acoustic transponder, and one for the releaser. Total power amounts to 120AH, and the total weight of the batteries is about 6kg.

## 5. Data Play-Back

Seismic data recorded on the magnetic tape are played-back using following procedures (see Ukawa et al., 1985 in detail).

### 1) Data Selection

Data on the original magnetic tape are reproduced by a play back recorder with a speed of 160 or 320 times that of the original recording in the OBS. To select data we usually record the highest amplified vertical component (90dB) and the time code signal on the visi-corder paper for several OBSs. In order to reduce visi-corder paper consumption, eight pairs of data (16 tracks) are recorded before exposing to light. Interesting events are selected and times of their occurrence are read, and punched onto the computer card.

### 2) A/D of Events

The original tapes are again reproduced to digitize parts of the record at chosen times at speed 80 times that of the recording in the OBS. The digitized data are stored in a computer magnetic tape.

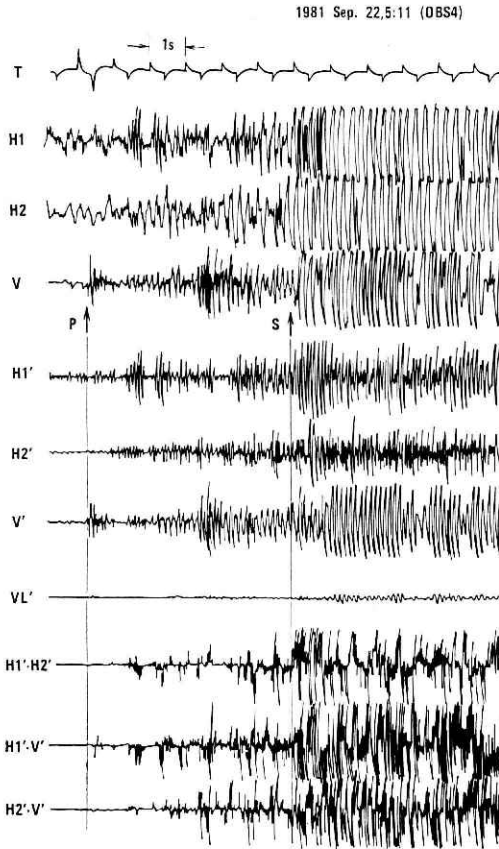
### 3) Seismograms

Seismograms are drawn on paper making use of a D/A converter. In the case of a natural earthquake we record digitized data only for those events recorded simultaneously at some chosen number of points. In making seismograms the vertical component record of all the points are reproduced on the same page of paper making use of a multi-pen recorder in order to facilitate the first motion reading.

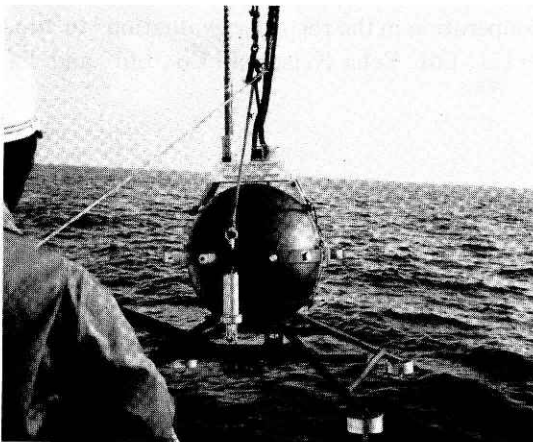
In Fig. 7 a typical seismogram obtained by the procedure is shown. The seismogram was obtained with the highest gain of 90 dB. From the top of the figure shown downward are time in BCD code with one pulse per second, two horizontal (H1,H2) components, vertical (V) component, the band-passed filtered (frequency range : 5 ~25Hz) H1, H2, V and VL components. The lowest three curves are time series of products between two of the three band-passed components to facilitate reading the first arrival of waves.

## 6. Launch and Recovery

Fig. 8 shows the CDPOBS IIa just before deployment. For the sake of safety, OBS is usually hung by two ropes when it is over the deck. One of the ropes is drawn when the OBS is over the sea surface. A pelican hook is attached to the remaining rope. A safety pin for the hook is drawn when the OBS is moved outside the deck. The hook is released by pulling a side rope with the result that the OBS is made free to drop into the sea. The operation of dropping the OBS is usually performed after immersion of the OBS into the water in order to reduce the dynamic shock as far as possible.



**Fig. 7** An example of a seismogram of an earthquake swarm obtained by pop-up type OBS4. From the top, downward are the time signal, two horizontal components H1, H2, vertical components V, with symbol dash(') and period(.) meaning band-pass filtering and multiplication, respectively.



**Fig. 8** CDPOBS IIa just before deployment.

During the descent we measure the distance, azimuth and inclination angles of the OBS with reference to the ship. The time of reaching to the sea bottom is judged by elapsed time from the dropping operation or by checking acoustic reflection signal from the ocean bottom a little later after direct signals. After landing we finally estimate the position of the OBS by measuring distances at more than two positions surrounding the OBS and the depth data, or by measuring the azimuth and inclination angles of the acoustic signal from OBS. Ship positioning is conducted by DECCA, or LORAN-C or GPS. Fig.9 shows an example of the determination of the position of the OBS. Points 1, 2, ... are ship positions at which the distance was measured, with *T* and *L* respectively being the dropping and an estimated OBS position on the sea floor. Before deployment and recovery of the OBS, the sea surface current is measured by GEK, and the amount of OBS drift during the course of descent or ascent is judged by assuming the current decreases linearly with depth to zero at a reasonable depth such as at 1,000m. Fig. 10 shows some examples of OBS drift during descent into the water, with the data of surface tidal current. The directions of drift nearly coincide with those of the ocean current. Deviation may be caused by the baroclinic component of the ocean current.

Almost all the release operation was performed by acoustic commands, which permitted recovery works to be conducted in a moderate sea condition. The rate of successful recovery is higher than 95%. A high rate of recovery depends on accurate positioning of the OBS, high reliability of the entire system, the checking method before deployment and good eyes of ship crews to find promptly the OBS after surfacing.

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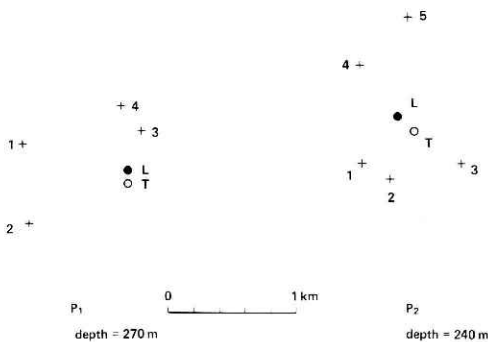
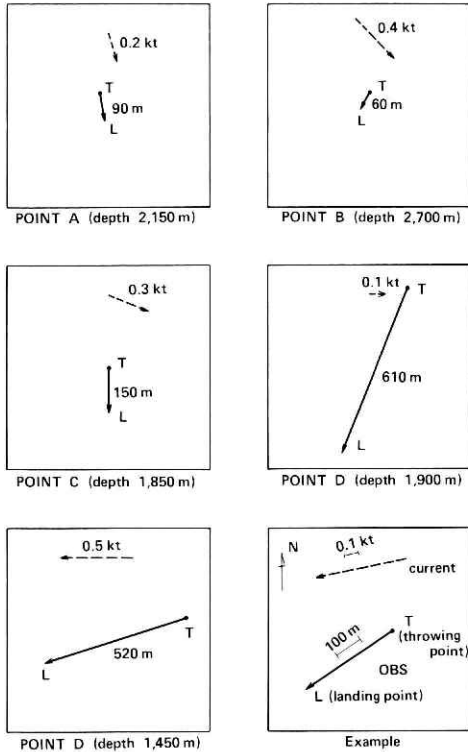


Fig. 9 Some examples of the OBS position determination. Points 1, 2, ... are the ship positions where the distance to the OBS were determined. Points L, T are the dropping point, estimated landing point of the OBS, respectively.

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**Fig. 10** Some example of OBS drifting during descent in the sea. Points T and L show throwing and landing point of OBS, respectively.

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## 自己浮上式海底地震計(CDPOBS IIa)について

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### 要 旨

海洋底で発生する大(巨大)地震の予知研究に用いる為に開発した自己浮上式海底地震計(CDPOBS IIa)について述べる。本海底地域震計の特徴は、

- (1) 水深6,000mまでの海底で繰り返し使用可能(アルミ合金製耐圧容器を使用し、最大残留歪は0.2%以下で、防蝕が施されている)、
- (2) 係留系を有せず、全体がコンパクトにまとまっている(球形耐圧容器)、
- (3) 水平2、上下1の3成分計測(ジンバルに搭載されており、方位計測機能あり)、
- (4) 広いダイナミックレンジ(各成分3段階増幅、周波数レンジ1~30Hz、低周波部分の帯域増幅)で地震計測が出来る、
- (5) 1,000時間にわたり、地震計測が安定になされる(高信頼性)、
- (6) 確実な回収がなされる(ラジオビーコン・フラッシュライトの併用、超音波信号による制御、切り離し機構の多重化、調整・チェックの標準化)、
- (7) 海底における位置が正確にできる(超音波信号による位置検知)、
- (8) 群列観測に使用する為、地震計の設置回収が容易である(クランプ機構、高い耐衝撃性)、
- (9) 電源用バッテリーの独立化(定常作動用にはリチウム電池、短期使用にはニッケルカドミウム電池)。

主に東海沖で行った性能確認試験を踏まえて、計測システム・作業方法は順次改良され、高い回収率を示している。

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