TIME BASE STABILITY OF OCEAN BOTTOM SEISMOMETERS (OBS)

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Abstract - During the past decades, Ocean Bottom Seismometers (OBS) have played a key role in permanent seismic activity monitoring at sea as well as allowing a better understating of the earth interior. Data collected by the instrument can provide information on the ocean bottom sub-layers down to a depth of 40 km beneath the ocean floor. The accuracy of the results directly depends on the temperature stability of the crystal used as the main time base of the equipment.

This paper presents the study of temperature stability of a Seascan module in real environmental conditions. By means of a climate chamber, temperature tests of a Seascan module were carried out and crystal temperature stability was calculated.

Keywords - Ocean Bottom Seismometer (OBS), stability, temperature.

I. INTRODUCTION

Over the past few decades, Ocean Bottom Seismometers (OBS) have gained special attention by the geo-scientific community. They are autonomous instruments that are deployed on the sea-bed up to depth of 6000 meters, where they collect sea floor vibration and water pressure data. The OBS is equipped with two main sensors: a tri-axial geophone composed of three SM6 accelerometers placed at right angle (one for each axis) inside aluminium housing, which collects the ocean bottom vibration, and a hydrophone that registers water pressure data. A side arm holds the geophone during the freefall and drops the sensor when the OBS is on the sea floor. The datalogger, battery pack and other necessary electronic modules are placed inside a glass sphere which is sealed by means of a vacuum holding both semi-spheres together [1]. Fig. 1 shows a picture of the OBS.

In passive seismology, the equipment collects ocean floor vibrations caused by a natural source (earthquake), where the objective is to determine the magnitude and location of the activity. Passive seismology demands an autonomy of about one year, but when the OBS is used in a sea-floor observatory, it is powered through a marine cable and has no power limitations.

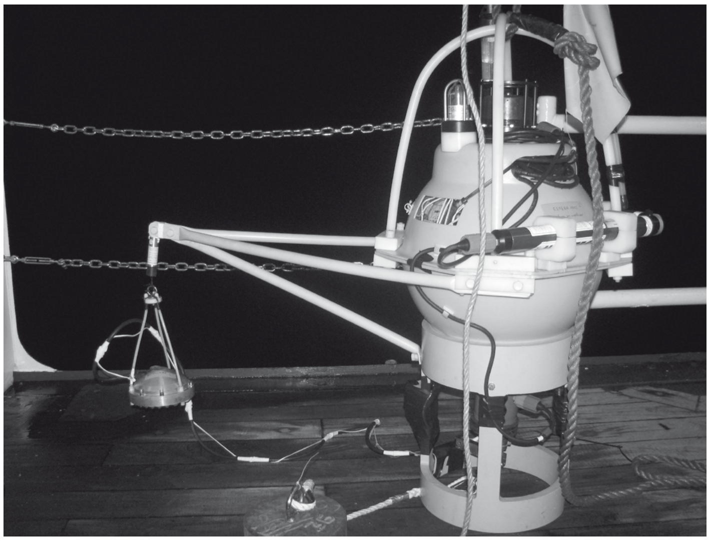


Fig. 1. Ocean Bottom Seismometer (OBS)

In active refraction experiments, a series of OBSs are deployed on the sea-bed and an artificial source (compressed air-gun) is dragged by the oceanographic vessel in order to generate acoustic signals every certain time during the experiment. The generated signal travels to bottom of the sea as well as through the earth being reflected and refracted by different ocean bottom sub-layers. These signals are collected by the OBS sensors, time stamped and stored in a compact-flash memory card.

When the experiment is over, an encoded acoustic signal is sent from the ship to the OBS which releases the anchor weight used to sink the instrument to the bottom of the ocean and the OBS rises to the surface due to its structural floatability.

In active seismology, after data processing in the lab, a map of the sea-bed down to a depth of 40 km beneath the ocean floor can be obtained, giving information on the width and material of each layer. In this case, the parameter that provides this information is the velocity of sound through different layers, which is estimated by accurate knowledge of the elapsed time between an acoustic signal generated by the artificial source and data collection by the OBS. It is known that the velocity of sound in the water column is 1500 m/s approximately [2]. While, air-gun shot timing is controlled by a GPS (Global Positioning System) [3] on the ship, the OBS has no access to such a signal for time synchronization during the entire experiment. The OBS clock is synchronized with a GPS signal prior to its deployment and clock time drift is calculated after OBS recovery by using the same signal. In the signal processing stage, data time marks are corrected assuming that the time drift of the OBS is linear during the experiment. While, marine institutes have put great effort in improving the data quality by minimizing the noise performance of the datalogger, the time mark correction of the data which has a direct effect on the final sound velocity model through the earth layers, has not been investigated in detail. This paper takes steps towards time drift characterization of ocean Bottom Seismometers by finding their temperature stability under real environmental conditions.

II. RESULTADOS Y DISCUSIÓN STABILITY CHARACTERIZATION

The main environmental parameters that affect the crystal oscillator output frequency are [4]:

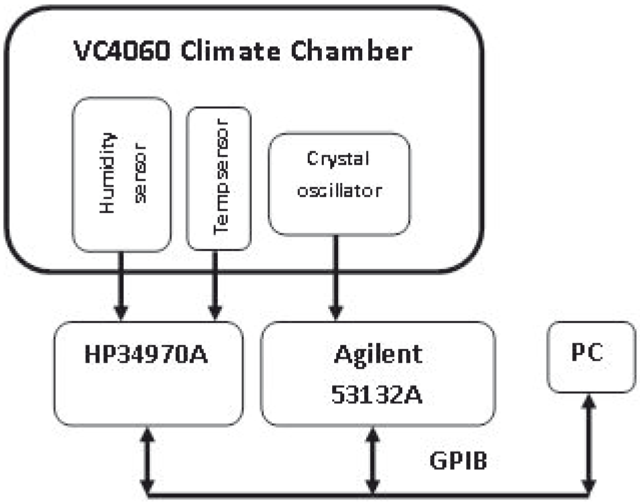
1-Temperature, humidity and Pressure
2-Acceleration effects
3-Electric and magnetic fields
4-Ionizing and radiation effects
5-Aging, warm-up and retrace

Due to design and operation of the OBS, the main parameter that is taken into account is temperature. As mentioned in the previous section, all the electronic modules are placed inside a glass sphere housing sealed under vacuum. The pressure inside the housing remains constant during the entire experiment and therefore does not affect the crystal oscillator. The OBS is designed to move at constant velocity of 1 m/s during the free fall and rising stage eliminating the effects of acceleration on the crystal. The time base module is placed inside a shielded box minimizing the effects of electro-magnetic fields and no ionization nor radiation takes place inside the instrument during the experiment. Parameters as aging and warm-up are given by the crystal manufacturer and frequency retrace does not affect the data as we are dealing with a time drift (time difference).

The crystal oscillator is placed inside a VC4060 environmental chamber where temperature is controlled.

In order to know the temperature close to the Seascan module, a temperature sensor is placed beside it and 4-wire measurements of the sensor is carried out. A HP34970A datalogger is used to measure the temperature and an Agilent 53132A universal counter with a temperature stability of 2.5 x 10-9 was used to measure the Seascan output frequency (125Hz). In order to obtain an improved resolution, frequency is measured within a time gate of 1s. The overall measurement system is controlled by a PC through a GPIB bus, where software in LabVIEW 8.5 takes measurements every 10 seconds. Fig. 2 shows the measurement system in the lab:

(Next Page) Fig. 2. Measurement system block diagram



During the tests, the temperature profile is configured to simulate the OBS real operation:

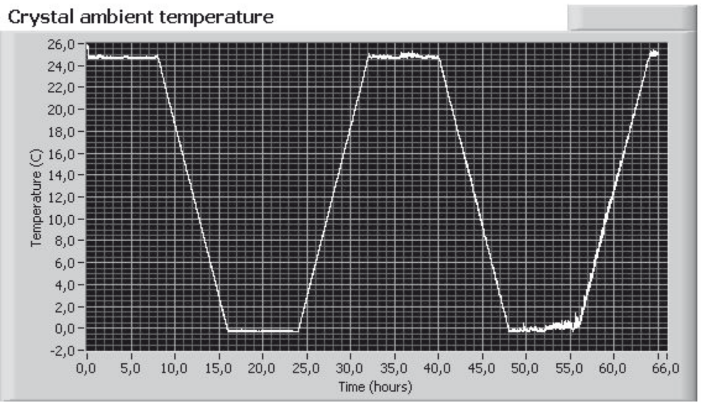
1-From 25 oC to 0 oC in 8 hours
2-At 0 oC constant for 8 hours
3-From 0 oC to 25 oC in 8 hours
4-At 25 oC constant for 8 hours

This profile was cycled twice to show data consistency. The time base module stability is calculated as:

$$Stability = \frac{f_i - f_{nom}}{f_{nom}}$$

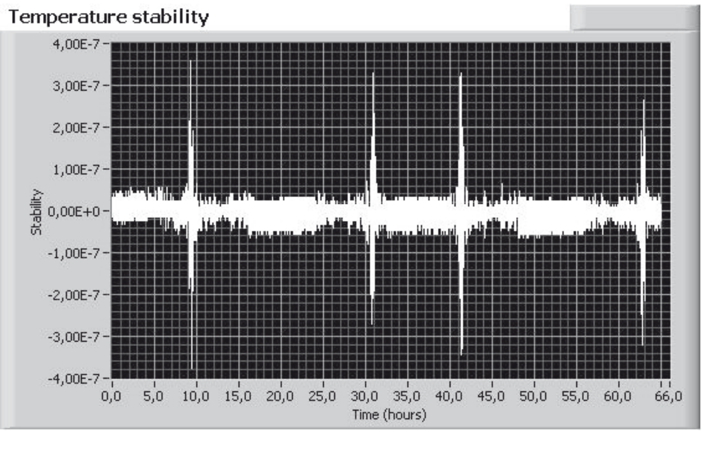
III. RESULTS

Figures 3 and 4 show the temperature profile and stability results of the test described in section 2 respectively. The test period was 65 hours.



(above) Fig. 3. Crystal ambient temperature during the test

(below) Fig. 4. Stability of the time base module



These figures show that the stability data are highly symmetrical and its mean value is ±1.3x10-8. Furthermore, when the temperature goes through 21 oC, the stability increases dramatically. In crystal oscillators, the temperature stability is highest at the turn over temperature [5]. At this temperature, the stability changes polarity. In order to find the turnover temperature of the Seascan module, The static frequency-Temperature (f-T) characteristic is found as:

$$\frac{\Delta f}{f_{nom}} = a_0 + b_0(T - T_0) + c_0(T - T_0)^2 + d_0(T - T_0)^3$$

Where T0 is 25 oC for an AT.-cut crystal. Figure 5 shows the f-T characteristic of the time base module when the temperature is increased from 0 oC to 25 oC:

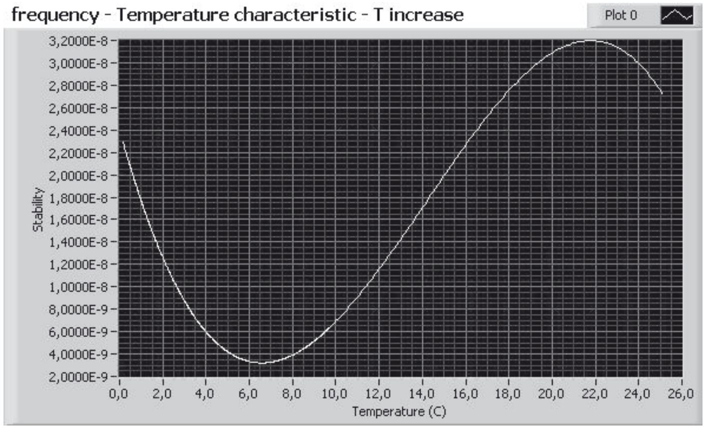


Fig. 5. f-T characteristic of the time base module.

The temperature coefficients of frequency are found to be:

a_0= 2.75 x 10-8
b_0= -2.92 x 10-9
c_0= -5.32 x 10-10
d_0= -1.64 x 10-11

Figure 5 shows that the f-T characteristics has a maximum at 21 oC (turnover temperature). The turnover temperature depends on the quartz property and its angle of cut.

IV. CONCLUSIONS

In this paper, the stability of a time base module used in most Ocean Bottom Seismometers (OBS) is investigated. The temperature was set to simulate the OBS operation and the mean stability is figured at ±1.3x10-8. The stability degrades around the crystal turnover temperature (21 oC). The f-T characteristics of the module is found by a 3rd order polynomial curve fit. In future work, the data presented in this paper will be used to characterize the time drift of Ocean Bottom Seismometers.

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V. Referenciases

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