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Ships and marine technology — Technical guidelines for active source exploration with ocean bottom seismometers (OBS)

Navires et technologie maritime — Lignes directrices techniques relatives à l'exploration des sources actives avec des sismomètres de fond de mer (OBS)

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Contents

Page

Foreword

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This document was prepared by Technical Committee ISO/TC 8, *Ships and marine technology*, Subcommittee SC 13, *Marine technology*.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

Exploration for the structures and movement of deep earth on the seafloor is one of the important approaches for human beings to recognize earth system evolution, predict seabed resources formation, and understand natural disaster mechanisms. Unlike the multi-channel seismic method which only obtains primary waves by hydrophone streamers on the ocean surface, the ocean bottom seismometer (OBS) is directly placed on the seabed and can receive both primary and shear waves, even Rayleigh and Love waves from earth interior. Such a new seismic method gives an opportunity to better image the structures, movement and rheology for the deep targets in solid earth beneath ocean which cover up to ≈71 % of the earth's surface. This method has been widely used in research on not only global continental margins, subduction zones, mid-ocean ridges, but also regional oil and gas fields, marine engineering constructions.

The signals received in OBS exploration can be either natural earthquakes or artificial excited seismic sources. Accordingly, OBS exploration is divided into passive and active source methods. Passive source exploration with OBS is a method by which OBSs just receive global natural earthquakes and obtain deeper and wider information from the earth interior. Active source exploration with OBS is usually used in a target region to reveal the structures, tectonics and composition of underground geological bodies or crust and upper mantle by a special designed array of OBSs and sources. Because of its strong pertinence, this active source method gradually becomes the main tool for regional deep earth exploration, and is widely used by industry and academia.

OBS is a mature technical product and widely used in various deep earth imaging. However, there is a lack of such a standard about active source exploration with OBS, which will seriously affect the testing, identifying, evaluating of the performance requirements and data quality of such products. It should therefore be necessary to standardize its technical requirements and basic procedures to promote healthy development of this industry of seabed OBS exploration. In view of the above, this document establishes the technical guidelines covering the main content of active source exploration with OBS from OBS instruments, seismic sources and fieldwork processes, to data services.

Ships and marine technology — Technical guidelines for active source exploration with ocean bottom seismometers (OBS)

1 Scope

This document specifies the technical requirements for system makeup, ocean bottom seismometer (OBS) instruments, active sources, field design, exploration operation, data processing for active source exploration with OBS, and their relative terms.

This document is applicable to active source exploration with OBS, but also a useful reference to the passive source exploration with OBS. It can be used in seabed resource exploration, geological disaster surveillance and submarine geoscience research.

2 Normative references

There are no normative references in this document.

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

3.1
ocean bottom seismometer
OBS
seismic observation system with a seismic sensor placed on the seabed to record ground motions and an acoustic sensor to record signals in the water column

Note 1 to entry: The main components include *seismic sensing system* (3.3) and *acoustic sensing system* (3.4), *recording and storage unit* (3.5), *release unit* (3.8), *acoustic communication unit* (3.7), compass, internal clock, power supply, lighting system, cargo compartment and protective cover etc.

Note 2 to entry: There are mainly two types of OBS, broadband and short period. The short period OBS, with the lower corner of its frequency band not less than 2 Hz, usually used for active seismic source exploration.

3.2
active source exploration
exploration method in which sound wave signals are emitted in the water by ship-borne seismic sources such as air gun, propagated downward through the crust and upper mantle, finally return to the seabed and recorded by *ocean bottom seismometers* (3.1)

Note 1 to entry: The crust and upper mantle information carried by ocean bottom seismometers is in the form of elastic wave.

Note 2 to entry: Active source is artificially excited at sea by physical or/and chemical means. Air gun sources are used in arrays.

Note 3 to entry: Multiple sources of same or different volume are towed at designed offsets and field at defined time delay to shape the resulting pressure wave used as seismic source.

3.3
seismic sensing system
system of earthquake sensing by *ocean bottom seismometer* (3.1) composed mostly of a low gain geophone or a high gain seismometer, mostly with three components, one vertical and two perpendicular horizontal components (XYZ) or, as an alternative, three identical sensors in three directions (UVW)

3.4
acoustic sensing system
system of sound sensing by *ocean bottom seismometer* (3.1) composed of a pressure sensor, mostly a high impedance hydrophone

3.5
recording and storage unit
ocean bottom seismometer (3.1) recording unit which is used to control data acquisition, signal filtering, signal amplification, analogue-to-digital conversion and storage

Note 1 to entry: The recording unit is composed of microprocessor and circuit components, the storage unit is composed of a buffer and one or more internal or external memory devices.

3.6
breakout box
device for *ocean bottom seismometer* (3.1) to set up a cabled or wireless communication for status checking or parameter setting

3.7
acoustic communication unit
acoustic wave sensing device which communicates with the *deck control unit* (3.9) through the acoustic wave, starts the release decoupling program, and sends the position or distance to the *deck control unit* (3.9) through the acoustic wave

3.8
release unit
device for driving the *ocean bottom seismometer* (3.1) placed on the seabed to separate from the anchor which is mainly composed of a physical fixing device, a power supply and a circuit, and is matched with an acoustic wave sensing device

Note 1 to entry: There are usually two release modes, one is that the deck unit drives the acoustic wave sensing device to start the release procedure, the other is to set the release start-up time in advance, and the built-in circuit and power supply realize the timing release.

Note 2 to entry: Release is usually accomplished by mechanical or electrochemical means.

3.9
deck control unit
acoustic communication device composed of a controller, a special cable and an acoustic transducer which is used to directly communicate with the *release unit* (3.8) or a built-in *acoustic communication unit* (3.7)

3.10
auxiliary recovery device
device which help to spot the *ocean bottom seismometer* (3.1) after emerging at the sea surface especially at night or during bad weather conditions

EXAMPLE Radio beacons, flash lights, AIS systems.

3.11
anchor
concrete block or ironwork that is used to provide weight (negative buoyancy) to ensure *ocean bottom seismometer* (3.1) fall free and couple well with the seafloor

Note 1 to entry: During recovering ocean bottom seismometers (OBS), the anchor is separated from the OBS and then disposed on the seabed. Some shallow water OBS use fixed reusable anchors and pop-up buoys for recovery.

4 Requirements

4.1 General

This document analyses the system makeup, performance requirements and quality control of active source exploration with OBS. It establishes the technical needs and basic procedures including reference/positioning system, instrument calibration, field design, OBS delivery, seismic sources, OBS recovery, exploration process, data acquisition and data processing, to promote standardized development of the OBS technology and its exploration.

4.2 Standard of time and space

4.2.1 Standard of time

Coordinated Universal Time (UTC) or local time shall be adopted.

4.2.2 Coordinate system

WGS84 coordinate system shall be adopted.

4.2.3 Vertical reference

Local mean sea level shall be used.

4.2.4 Positioning system

Global Navigation Satellite System (GNSS) positioning system shall be adopted.

4.3 OBS technical indicators

4.3.1 OBS acquisition system

The OBS sensor system usually consists of a 3-component seismic sensor and an acoustic sensor, corresponding to the seismic sensing system and the acoustic sensing system, respectively. OBS acquisition system shall be in accordance with a) to e) below.

a) On the lower corner of the frequency band for velocity seismometers, the short-period OBS shall not be less than 2 Hz.

b) The sampling frequency of OBS data recorder shall not be less than 20 Hz.

c) The internal clock shall be provided with absolute time service and the linear clock drift is less than 3 000 ms/y.

d) The dynamic range shall be not less than 120 dB.

e) The pressure resistance of OBS equipment cabin and acoustic sensor shall comply with a water depth which is deeper than the actual working water depth instructed by manufacturers.

4.3.2 OBS deployment/recovery system

The OBS shall have at least one set of built-in release unit which is on-site acoustic recovery or with timing floating for special exploration and environmental protection. OBS deployment/recovery system shall be in accordance with the following.

a) The buoyancy of the OBS shall ensure a rapid rising to minimize lateral drift during ascent which maximum rising velocity depends on the type of OBS, typical ranges are 0,3 m/s to 1,5 m/s.

b) The anchor shall match the OBS weight, with a settling velocity from 0,3 m/s to 1,5 m/s.

c) The anchor shall be designed in a way to keep the OBS balanced in air as well as in water.

d) The OBS shall have an independent tracking device for day and night recovery, like flags, radar reflectors, flasher, radio beacons, AIS or satellite-based systems.

e) The attitude of OBS after reaching to the sea level shall ensure normal communication between the release auxiliary equipment (tracking devices) and the search source.

4.3.3 Power supply system

The power supply system shall provide the power for the recording unit and release unit of OBS, and shall be in accordance with the following.

a) The nominal capacity of the battery used by the OBS for recording shall be more than 1 time the capacity required for the acquisition operation.

b) The nominal capacity of the battery used by the OBS for release shall be more than 1 time the capacity required for the release operation. The power supply for the release unit shall be independent from the power supply for the recording unit. A third power supply for the time release is recommended.

4.4 Seismic sources

Seismic source is an important part of active source exploration with OBS, the most popular marine seismic sources include airguns, sparkers and boomers. The seismic sources shall:

a) choose an appropriate seismic source for different exploration targets;

b) determine seismic source parameters, such as energy capacity, air pressure, gun array assembly, dominant frequency range, towing depth and shooting interval by seismic simulation and practical tests according to the nature, structure and depth of exploration target, and also the requirements of accuracy and resolution of exploration.

4.5 Field design

The field design shall meet the following criterion.

a) Suitable seismic source and OBSs are chosen for different water depth and exploration targets of the study area.

b) The direction of the main survey line is adjusted according to different exploration targets. Normally, the main survey line is perpendicular to the tectonic strike.

c) The spatial resolution of the exploration is mainly controlled by OBS station spacing and seismic source density. The higher the resolution is needed, the smaller OBS station spacing and higher seismic source density should be designed.

d) The capacity and frequency of seismic source match with the exploration depth of the study area; the higher energy and lower frequency of seismic source is usually designed for deeper exploration targets.

e) The shooting time interval is adjusted according to the exploration target and vessel speed, and designed to avoid the signal interference from both direct water-wave arrivals and water peg-leg multiples generated by the preceding shot.

4.6 Marine exploration process

4.6.1 OBS preparation

OBS preparation shall be in accordance with the following.

a) Conformance test

Before OBS deployment, conformance tests should be applied to all OBSs in the land laboratory, including internal clock, sampling rate and vibration response.

b) Function test

A set of installed OBS shall be tested to ensure good functioning after battery charging, air-tightness test, communication test and other maintenance.

c) Consumables and spare parts

It shall be equipped with enough consumables (e.g. seals, dry packs, detergents) and spare parts (e.g. data logger, geophones).

d) Auxiliary equipment

It shall be equipped with more than a deck control unit, GNSS system, vacuum pump and other auxiliary equipment respectively (if glass ball sealing is required on board).

e) Function test

Before OBS deployment, all mechanical connections and electronic components (e.g. data logger, battery voltage, release unit) shall be tested, and the test reports should be provided.

4.6.2 Relevant software, media and files

The relevant software, media and files shall include:

a) OBS software including OBS operating software and files installed in the computer in advance;

b) file forms including OBS deployment/recovery forms, parameter setting forms, conformance test forms and other record files;

c) storage media including adequate storage media in place to hold at least two copies of the original data backup.

4.6.3 OBS parameter setting

OBS parameter setting using breakout box shall include the following:

a) Sampling rate setting: the data sampling frequency of OBS shall be chosen according to the specific detecting targets and data processing requirement, the parameter value should be selected from the sampling frequency range provide by the instrument.

b) Clock setting: the start and stop time of recording and the automatic release time should be set based on standard time with GNSS in internal clock, and the specific parameter values should be in accordance with the voyage planning time.

c) After the parameter setting, the operator shall sign the parameter setting form.

d) Input gain / preamplifier: shall be set according to the scientific objectives.

4.6.4 Glass ball sealing

Glass ball sealing shall:

a) clean the cabin ball and contact surface by cleaning agent before sealing the ball;

b) measure the release voltage in time and ensure it is zero;

c) if possible, keep OBS out of the direct sunshine in a room with normal temperature on the ship and wait for deployment, and regularly monitor cabin pressure and voltage, and make records; reset and install OBS while air leakage and abnormal voltage is found;

d) test the release device effective response to the deck unit again before deployment, otherwise re-checking OBS, the OBS not being deployed unless the problems resolved;

e) record the instrument number, acoustic release code, communication frequency and planned release point of OBS;

f) sign relevant forms by operator after the sealing setting is completed.

4.6.5 Pressure tubes

OBS with pressure tubes shall be prepared according to the manufacturer's instructions. Special emphasis shall be laid on the sealing of the tubes.

4.6.6 OBS deployment and recovery

OBS deployment and recovery shall include:

a) Anchor installation

The anchor is ensured to rigidly connect with the OBS and check whether the release device is reliable.

b) Final check

A final check shall be performed prior to deployment for all devices and units, ensuring that all connectors are plugged in, all screws are tightened, recording and storage units are switched on and running.

c) OBS deployment

The ship deploying OBS shall move at low speed, normally at less than 2 kn (1,03 m/s) without strong current and wind status. OBS shall be as close to the sea surface as possible to unhook after entering the water.

The position deviation between actual deployment and design point shall be less than 5 % of water depth. The actual ship information of position and heading, and its relative unhooking point shall be recorded immediately.

d) OBS release

The time for OBS return to sea surface shall be estimated. Depending on deployment offsets, water depth and weather conditions, OBS release command can be transmitted in advance to next recovery position reducing waiting time. After receiving the release signal, the acoustic communication unit patched in the OBS responds automatically.

The instrument rises while the vessel approaches recovery position. Acoustic transducer of the deck unit built in the hull can be used for release command transmission while the ship sails slowly towards recovery position.

If OBS does not reach the sea surface upon arrival of the vessel, the ship shall stop in a certain distance from the deployment point depending on water depth, currents, wind and wave heights.

Use a hull mounted acoustic transducer or put the acoustic transducer of the deck control unit into water at a depth exceeding the draft of the ship, far away from the propeller, keeping vertical state, then send the release command.

In case of communication problems, any acoustic equipment and sound source shall be switched out to avoid interference.

If the OBS does not respond to the release order, the ship may move on different directions centred on the deployment point, and multiple attempts should be made at different distances. Shallow thermoclines can disturb acoustic communication, attempts with different transducer depths should be made.

If communication still fails, wait at least 1,5 times the estimated rising time after the last release command before leaving the site.

e) OBS recovery

The flotation time shall be estimated according to the water depth and the average flotation velocity of the OBS, looking out outside the cabin in advance, searching with auxiliary recovery device. When the OBS on the sea surface is found out, the acoustic transducer is recovered first, and then the ship is sailed to salvage the OBS, immediately recording the recovery position information, cleaning and drying the OBS.

4.6.7 Voyage requirements

Voyage shall meet the following requirements when there are stable sea conditions and no obstacles.

a) When carrying out a straight seismic shooting operation, the vessel speed and direction should remain stable with 4 kn to 5 kn (2,06 m/s to 2,57 m/s), and the deviation distance from the designed survey line should not be more than 20 m.

b) When carrying out an arc seismic shooting operation, the vessel turning around shall be calculated according to the length of the gun cable to ensure safe radius.

4.6.8 Timing and positioning

The timing and positioning shall meet the following requirements when there are stable sea conditions and no obstacles.

a) The shotpoint coordinates and OBS deployment/recovery coordinates shall be all determined by the ship-borne GNSS positioning system, with the highest possible accuracy.

b) Professional navigation system and built-in GNSS chronometer time recorder shall be employed to precisely record the GNSS time of gun-controlled excited signals with an accuracy of 1 ms, for precise correction of shooting time of the gun matrix system. The other mode shall place a built-in GNSS short-cycle seismometer to record the deck pulse signals during shooting for the purpose of shot time correction.

c) The distance between the air gun shotpoint and the shipborne GNSS antenna shall be accurate to 1 m, and the shotpoint coordinates and OBS location shall be corrected during data processing.

4.6.9 Operation log

The operation log shall include:

a) real time monitoring the seismic source, including capacity value, synchronization value, focal depth and waveform, and recording the controlled shooting during the seismic shooting operation;

b) real time monitoring the navigation system, including longitude and latitude, heading, ship speed and water depth, during the seismic shooting operation;

c) timely checking the time synchronization, recorded data quality and working status of the recovered OBS instrument;

d) if any abnormal, improving or stopping the operation in time.

4.7 Field data

4.7.1 Raw data

The raw data shall include:

a) source data of seismic source records, timer records, navigation and positioning data, and voyage logs;

b) OBS data of raw data, converted common seismic formats data (such as SEGY and SAC), internal records logs, deployment/recovery records;

c) bathymetry data.

4.7.2 Relevant data

The relevant data shall include:

a) OBS check and maintenance records, and deployment/recover records on board;

b) regional topographic map;

c) regional water sound velocity;

d) relevant geological data and gravity data;

e) work area location map, station location map and navigation track map.

4.8 Data processing and archiving

4.8.1 Data processing

Data processing shall include:

a) shotpoint positions correction including correcting shotpoint coordinates according to the distance and azimuth of shipborne GNSS equipment to the centre of air gun matrix, and forming shotpoint coordinate files;

b) shotpoint time correction which shall correct the shooting time according to the aforementioned precise time records, forming the shooting time files, processing the shotpoint-related files and ensuring one-to-one correspondence of various shotpoints in time and position;

c) OBS coordinate forecasting which shall take deployment coordinates and water depth as the forecasting location of the OBS before position correction, and forming OBS coordinate files;

d) OBS relocation which shall correct OBS coordinates through theoretical direct waterwave modelling for OBS exploration;

e) OBS time drift correction which shall include linear correcting on the recorded OBS time data according to the clock difference value recorded in the clock drift file;

f) the least square method used to project shotpoint coordinates and OBS coordinates onto the profile;

g) filtering method to improve the signal-to-noise ratio of seismic data;