



Exploration & Production

GENERAL SPECIFICATION

SURVEYS

GS GEO 302

Subsea positioning works

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1. Scope

The objective of this Specification is to ensure that the subsurface positioning requirements of COMPANY during offshore operations are met. This Specification is designed to be complementary to the project Scope of Work which outlines the nature and the requirements of the entire project.

CONTRACTOR shall carry out the subsurface positioning aspects of the project with professional competence in accordance with the standard of the professions of the industry and to the satisfaction of COMPANY. CONTRACTOR shall perform the positioning tasks with qualified personnel and equipment, which is in perfect working order. CONTRACTOR shall retain its equipment and personnel for the exclusive use of COMPANY for the duration of the survey.

Additionally the objective of this Specification is to provide reliable three-dimensional underwater positioning for operations conducted by companies within the Total Project, for any subsurface structure installations, drilling operations or ROV Survey tracking. This Specification is to be used in conjunction with the other documents referred to in section 2 and 3 as well as the COMPANY Particular Specification.

2. Reference documents

The reference documents listed below form an integral part of this General Specification. Unless otherwise stipulated, the applicable version of these documents, including relevant appendices and supplements, is the latest revision published at the EFFECTIVE DATE of the CONTRACT.

All documents referred to in this section shall be considered as the latest versions and it shall be CONTRACTOR's responsibility to ensure that CONTRACTOR is in possession of these particular documents and that any qualifications are valid.

Standards

Reference	Title
BS EN ISO 9001: 1994	International Standards Organisation 9001: 1994 which is part of the ISO 9000 series and addresses Quality Systems - Model for Quality Assurance in design, development, production, installation and servicing. Equivalent to BS 5750 and EN 29000
BS EN ISO 9002: 1994	International Standards Organisation 9002: 1994 which is part of the ISO 9000 series and addresses Quality Systems - Model for Quality Assurance in development, production, installation and servicing. Equivalent to BS 5750 and EN 29000

Professional Documents

Reference	Title
UKOOA Guidelines	Guidelines for the Measurement of Quality and Basic Quality Control of Offshore Positioning Data published by the UKOOA Survey and Positioning Committee, June 1992
UKOOA Guidelines	Guidelines for the Use of Differential G.P.S. in Offshore Positioning published by the UKOOA Survey and Positioning Committee, September 1994
UKOOA Guidelines	Guidelines for the use of DPPS for offshore positioning published by the UKOOA surveying and positioning committee in 1994
Not applicable	

Regulations

Reference	Title
Not applicable	

Codes

Reference	Title
Not applicable	

Other documents

Reference	Title
Not applicable	

Total General Specifications

Reference	Title
GS GEO 301	Offshore surface positioning works
GS GEO 304	RTK positioning for bathymetric and geophysical survey

3. Scope of work

3.1 Positioning Systems

CONTRACTOR shall ensure that all specified navigation and positioning equipment including computer hardware and software are installed, calibrated and operational. The positioning work shall only commence with all systems fully functioning.



Both surface and subsurface systems shall be integrated to the main survey computer in order to provide the most accurate and reliable absolute position of the surface and subsurface equipment.

The CONTRACTOR shall supply the underwater positioning systems, which shall provide the solution with sufficient redundancy, and quality control output in order to assure that positioning is within the required accuracy.

The minimum equipment required will be in relation to the different stages of the project and in accordance with the required accuracy:

- Long Base Line (LBL) acoustic navigation using Medium Frequency or Extra High Frequency
- Short Base Line (SBL) or Ultra Short Base Line (USBL) acoustic positioning system
- Combined LBL and USBL (LUSBL) acoustic positioning system.

The highest standard of the accuracy shall be obtained with the LBL acoustic system working with associated intelligent transponders and acoustically telemetered data to the surface, while the lowest accuracy will be obtained with the SBL acoustic system. Additional equipment to improve the standard performance of the different acoustic systems may be supplied to achieve the COMPANY's requirements.

CONTRACTOR shall provide all other equipment, if not specified herein, to ensure fully operational systems, which satisfy COMPANY's specifications.

All necessary spare parts, operation and maintenance manuals shall be provided onboard the vessel.

CONTRACTOR shall measure all offsets prior to each survey, after each modification and at any other time on the request of the COMPANY Representatives. All offsets and any changes shall be logged and displayed in the form offset lists and diagrams.

The Subsurface Positioning Service shall allow the user of this service to position the indicated object continuously during the required time and in the specified tolerance (at 95 % confidence level) anywhere in the desired area or zone of operations. The accuracy requirement in absolute co-ordinates will be dependent on the operation phase and will be up to ± 2 m in case of strong requirement while only ± 10 m could be required for systematic pipe laying. For relative positioning or metrology purpose, the accuracy requirement is ± 0.1 m in relative co-ordinates.

Positioning acoustic transducers shall be installed such that shadowing and reflections of the signals are minimised and that there is no interference from other transmitters. Every effort shall be made to install the transducer at the lowest point on the vessel.

All offsets to and from reference points on the vessel (including the heights) shall be physically determined by acceptable survey methods.

All raw data will be time tagged to GPS or UTC time, logged in a format and on an agreed medium agreed by COMPANY.

3.2 Water column parameters

CONTRACTOR shall follow the guidelines included in the document annexed in appendix Specification for the use of under water acoustic positioning.



The sound velocity shall be considered, as a fundamental parameter in achieving subsurface positioning accuracy and the positioning software shall be able to integrate the full column velocity profile if required.

CONTRACTOR shall measure the sound velocity parameters prior to and after each survey, and at any other time on the request of the COMPANY Representatives. This request shall be dependent on the acoustic system in use. The full water column measurements shall be required in the case of SBL or SSBL use while the sea bottom sound velocity parameters will be sufficient in the case of the use of LBL with acoustic telemetering of the data to the surface.

The equipment supplied by the CONTRACTOR shall be able to determine the sound velocity within ± 1.5 m/sec and it shall be calibrated according to the MANUFACTURERS recommendations and known standards. The calibration shall not be more than one month old.

Documentation of procedures, calibration details and methods of computation shall be presented to COMPANY prior to fieldwork.

3.3 Noise considerations

CONTRACTOR shall ensure that the acoustic noise level of the vessel or the support ROV shall not affect either the maximum range capability of the acoustic positioning system, or the range timing precision (or jitter) of an acoustic measurement.

CONTRACTOR shall also ensure that there is no interference between the other acoustic systems working in the operational vicinity (e.g. acoustic signals from a Dynamic Positioning System of a vessel).

3.4 Deep water considerations

CONTRACTOR shall modify if necessary standard equipment to overcome specific deep water problems.

3.5 Orientation

Orientation of the ROV in Subsea positioning shall come from the gyro. The precision of the determination of orientation must be proved to COMPANY prior to mobilisation and submitted to COMPANY as part of the Quality Project Plan. The orientation shall form part of the computation of all offset positions and where applicable a simultaneous adjustment of the positioned network.

If required, accurate orientations of Subsea structures shall be derived from the metrology measurements performed with the LBL positioning system.

3.6 Survey datum and transformation

Initiation of the navigation software on board the vessel shall be done in the presence of COMPANY representative. All geodetic data, spheroid and projection parameters, datum shift values shall be printed and agreed by COMPANY representative before start of navigation.

Transformation from WGS-84 to local datum shall be tested, using a set of co-ordinates provided by COMPANY.

4. Personnel

All personnel who operate the Subsurface acoustic positioning systems shall be suitably trained.



The survey team shall consist of sufficient personnel to permit 24 hour operations. There shall be a Chief surveyor who will be responsible for the management of the survey team, supervision of shifts and liaison with COMPANY Representative. There shall be at least one senior surveyor on each shift.

The Chief and senior surveyors shall have a degree in surveying or an acceptable equivalent. They must be capable of understanding the requirements of the Specification, the reference documents, the Scope of Work and translating them into practice.

These personnel shall not be reassigned without the prior approval of COMPANY.

5. Destination for positioning data, reports and plots

CONTRACTOR shall be informed in the Contract of the destination for the positioning data, reports and plots.

6. Quality System

6.1 General

The CONTRACTOR shall be managed by an effective Quality System that ensures conformance to agreed requirements and provides adequate confidence that the product or service fulfils requirements for quality. The requirements of [BS EN ISO 9001](#) (or [9002](#)) 1994 shall be met.

The Quality System shall comprise the:

- Quality Manual
- Management Procedures
- Work Instructions (including those specific to the project)
- Records, Reference and Support Documentation.

These shall be in the English language and available for inspection by COMPANY.

6.2 Quality plan

The CONTRACTOR shall propose a comprehensive Quality Plan covering all aspects of the services and which satisfactorily relates the Quality System to the Scope of Work to the satisfaction of the COMPANY.

The Quality Plan shall contain the minimum of the following:

- A description of the CONTRACTOR's organisation which specifies those individuals responsible for achieving compliance with the technical and quality requirements of the Work
- The Work Instructions used for each survey activity
- A list of the objective documentation to be produced as proof of achievement of the requirements



- The criteria used to measure the acceptance of acquired data including algorithms where applicable
- Precision of the services to be carried out by SUB-CONTRACTORS and the methods used by CONTRACTOR to assess and control these services.

6.3 Quality Audits

The COMPANY shall reserve the right to assess the technical capacity of and review the effectiveness of Quality Systems implemented by the CONTRACTOR and its SUB-CONTRACTORS. This may be affected by means of surveillance, review and audit methods at the discretion of the COMPANY.

The CONTRACTOR shall maintain similar methods to assess and review their SUB-CONTRACTORS. The records should be available to the COMPANY.

6.4 Project Quality Plan

The Project Quality Plan shall set out the specific Quality practices, resources and sequence of activities relevant to the Contract. It should follow the guidelines included in the document Guidelines for the Measurement of Quality and Basic Quality Control of Offshore Positioning Data published by the UKOOA Survey and Positioning Committee, June 1992.

The Quality Project Plan shall be submitted to COMPANY at least one month before mobilisation. The Quality Project Plan shall describe the CONTRACTOR's methods by which it shall ensure conformance to requirements and positioning tolerances. With close reference to the CONTRACTOR's procedures and work instructions, the Project Quality Plan shall detail the CONTRACTOR's positioning systems, survey sensors, methods techniques and general configuration by which the positioning objectives will be met. The CONTRACTOR shall ensure that all specified navigation and positioning equipment including computer hardware and software are installed, calibrated and operational.

These shall include at the very minimum the following:

- Comprehensive descriptions of all proposed subsurface positioning equipment and systems. Where the systems are sub-contracted, then performance figures shall be provided as well as details of CONTRACTOR's audits on the SUB-CONTRACTOR. Monitoring systems shall be described as well as any other relevant information. Types of acoustic equipment shall be itemised.
- Line listing and pre-plots together with the agreed geodetic parameters.
- List of calibrations to be carried out as well as the methodology and procedures to be used. Historical data from previous calibrations will be provided where applicable.
- An analytical appraisal of the positioning configuration. This shall comprise as absolute minimum a description and analysis of all nominal offsets, geometry, redundancy, nodes, a priori standard deviations of all of the observations and where applicable the correlation coefficients between the observations. Any other relevant information must be included. The analysis shall be applied to the survey networks and the results supplied to COMPANY on a 3.5" diskette. Any tracking nodes shall be identified. Scenarios of realistic equipment breakdown shall be included. A hard copy shall be supplied by fax or courier.

A block diagram of the structure of data acquisition and processing including the individual systems shall be supplied.



- Description of all real time and off-line data processing methods. The methodology of the computations shall be described as well as the statistical output and testing involved to ensure that all significant errors are readily detected. Any proposed changes to existing onboard systems or software shall be detailed. Any filtering methods shall be fully documented and made available to COMPANY prior to the commencement of the survey. CONTRACTOR shall clearly indicate whether processed data is Kalman filtered or computed by Least Squares for each point.
- All other quality controls and measures that concern processing of positioning data shall be described and in context with the processing set up.
- Percentage of and type of spare equipment and contingency for the replacement or repair of defective material.
- The magnetic declination for the survey area.
- Details of the survey team, including names and brief CV'S.

The CONTRACTOR shall prove to COMPANY that the proposed configuration of positioning systems and sensors is capable of achieving the required precision and that sufficient redundancy exists to ensure valid statistical results and to maintain the required precision in case of certain levels of equipment failure.

COMPANY reserves the right to request changes and to add further specified procedures if considered necessary.

6.5 Documentation on board

A copy of all Quality System documentation which shall be made available to COMPANY Representative.

Documentation pertaining to the equipment used, positioning systems and geodetic parameters, calibration data (including historic data where applicable), system parameters and configuration, correction values, and offset diagrams information. Printouts from all processing systems shall be produced and stored. This information shall be made readily available to COMPANY Representatives.

A Mobilisation Report shall be furnished to COMPANY Representatives. This will include details and parameters of the positioning systems, the report on all terrestrial calibrations in its final form (including historic data where applicable), online and offline system parameters and configuration, correction values, and offset diagrams information, network design diagrams, pre-plots and this shall be passed to COMPANY Representatives no later than at the departure of the vessel.

Any pre-survey offshore calibrations, checks or changes of offsets shall be fully documented and presented to the COMPANY Representative within 24 hours of execution.

A detailed daily log of all significant chronological events shall be recorded and will include system and equipment changes as well as any parameter changes. Logs shall be maintained of all calibration or equipment checks whether in port or at sea, whether static or dynamic in nature. Logs shall be maintained of all system malfunctions and all other details concerning any aspect of vessel positioning shall be clearly noted. Trails of any remedial action or maintenance shall be kept. All of this documentation shall be made available to COMPANY Representatives at any reasonable time.



6.6 Onboard data processing

Processing (real time and post processing) of all positioning data shall be carried out onboard. Any linking or identification with survey records shall also be completed onboard.

CONTRACTOR will provide equipment and personnel to ensure that the following have been completed within 24 hours of acquisition:

- Positioning data has been checked and processed
- Statistical output proves that the data conforms to the required precision
- Raw data has been recorded in the relevant and agreed format. All raw data will be time tagged to GPS or UTC time, logged, and stored on a prior agreed medium
- Final processed data has been recorded in relevant and agreed format and stored on a prior agreed medium
- The COMPANY Representative has received the data and the statistical output which should prove the conformance of the data to required specification.

CONTRACTOR's system shall be capable of storing raw data for the entire survey on a suitable and agreed medium.

If the stored raw data has been in any way filtered, smoothed or had C-O's applied within the individual sensors, then this shall be clearly indicated.

All maps and plots shall clearly refer to the geodetic Datum, spheroid and projection. Geographical and rectangular grids shall be drawn. The map and plot files shall be in DXF or DGN format.

CONTRACTOR's integrated navigation system shall be capable and be used to perform the very minimum of the following:

- QC report which shall demonstrate and prove with statistically acceptable indicators that the required Specifications have been met. These indicators shall also demonstrate the quality of the positioning data using statistically acceptable indicators. This report shall be presented to the COMPANY Representative on the completion of each operation.
- Collection and analysis of data over the duration of the operation in order to monitor trends within the positioning data.
- When possible, comparisons between the different available positioning systems.

All geodetic data, system offsets and system parameters (including acceptance criteria and filtering levels) shall be output, submitted to and approved by COMPANY Representative.

6.7 Calibrations

The calibration of all positioning systems and sensors is strictly the responsibility of CONTRACTOR. Calibration procedures shall be documented as part of the Quality System and will be subject to the COMPANY approval. Each calibration shall be carried out with a technique suitable to the equipment concerned and conforming to MANUFACTURER's instructions. CONTRACTOR shall strictly follow their own Procedures which have been approved by COMPANY. CONTRACTOR shall immediately inform COMPANY if these Procedures cannot be followed so that new Procedures may be agreed.

All calibrations shall be carried out by qualified staff and witnessed by a COMPANY Representative.



A report on the calibrations, together with all observations and calculations, carried out at mobilisation shall be completed and submitted to COMPANY Representative before the vessel sails.

No uncalibrated equipment or equipment components shall be used during operations.

The minimum equipment to be calibrated (where supplied) shall be:

- Gyrocompass(es)
- Fathometer(s)
- Sound velocity measurement equipment
- SBL or USBL
- Additional sensors which may provide relevant information (e.g. pressure gauge).

The minimum equipment to be verified (where supplied) shall be:

- LBL equipment
- All other equipment that may be contractually used.

On COMPANY request, positioning sensors shall be checked at the demobilisation of the vessel using the same procedures used at the mobilisation.

CONTRACTOR shall also check any other equipment at mobilisation or demobilisation that COMPANY considers doubtful and requires verifying.

6.8 Final Report

CONTRACTOR shall supply within 30 days of the completion of the survey a Final Field Operations Report concerning all positioning aspects and which shall include all real time and post processing operations.

The report shall include the minimum of:

- Introduction
- Survey Methods
- Hardware and software used
- Description and assessment of all survey software used
- Details of survey networks including diagrams
- Navigation personnel
- Survey Methods as well as geodesy, offsets and statistical parameters
- Description of processing of the data, QC summaries, network adjustment results and problems encountered including:
 - Quality indicators (standard error of unit weight, error ellipses, W and F test results, etc.) for the network adjustment
 - A priori standard errors
 - Lists of observations rejected and by which test
 - Number of adjustments



- QC statistics such as standard deviations, maximum and minimum observations
- Lost data for any reason.
- All relevant statistical information including:
 - Positioning systems used
 - Quality indicators
 - Lost or rejected points.
- Calibration Reports
- Data storage listings
- Post plot map
- Conclusions, Summary and Recommendations.

All maps and plots shall clearly refer to the geodetic Datum, spheroid and projection. Geographical and rectangular grids shall be drawn.

All final data shall be provided to COMPANY in P5/94 UKOOA Data Exchange Format (pipeline positioning data), and as graphic data files in Microstation format (xxxx.DGN). The media requirements are those contained in the P5/95 UKOOA data exchange format specification.

Appendix 1 Definitions

C-O	Computed minus Observed correction
COMPANY	Total E&P, its Subsidiaries or Associates
CONTRACTOR	Positioning COMPANY that has been contracted by Total E&P, its subsidiaries or Associates to carry out an offshore survey
DGPS	Differential Global Positioning System which uses corrections from a known reference station
EHF	Extra High Frequency
ITRF	International Terrestrial Reference Frame
LBL	Hydroacoustic Long Base Line System
MF	Medium Frequency
PDOP	Position Dilution of Precision
QC	Quality Control
Quality Audit	A systematic and independent examination to determine whether Quality activities and related results comply with planned arrangements and whether these arrangements are implemented effectively and are suitable to achieve objectives
Quality Manual	A document stating the Quality Policy, and describing the quality system of an organisation
Quality Project Plan	Document setting out the specific Quality practices, resources and sequence of activities relevant to the particular project
RINEX	Receiver Independent Exchange Format
Representative	Positioning Representative acting on behalf of COMPANY
ROV	Remote Operated Vehicle
Scope of Work	Document produced by COMPANY which details the particular requirements for a particular project
SUB CONTRACTOR	COMPANY providing services to CONTRACTOR as part of project contract
USBL	Hydroacoustic Ultra Short Base Line System
Topographical Dept.	Topographical Department of Total E&P, CMP, Pau
UKOOA	United Kingdom Offshore Operators Association
UKOOA Guidelines for the use of DGPS for Offshore Positioning	Guidelines published by UKOOA Surveying and Positioning Committee in 1994
UTC	Co-ordinated Universal Time
WGS-84	World Geodetic System 1984

Appendix 2 Specification for the use of underwater acoustic positioning

1. Objective

The objective of this Specification is to provide reliable underwater three dimensional positioning for operations conducted by companies within the Total. CONTRACTOR shall refer to the Scope of Work for the particular requirements of the project as well as the relevant Specification for the positioning of that type of project.

This specification defines the minimum underwater positioning requirements and the operation of systems for any subsea structure installations, drilling operations or ROV Survey positioning to be used for the project. All systems provided for work on the project shall comply with the relevant requirements of this specification.

This Specification is to be used in conjunction with the COMPANY Specification for the Offshore surface positioning works.

2. Definitions and abbreviations

2.1 Definitions

2.1.1 Accuracy

Accuracy may be defined as the extent to which an estimate approaches its parameter, but in conventional terms it is considered to be the degree of closeness to the "true" value. When in this specification, accuracy has figures with a deviation from the "true" value, these deviations are considered as $\pm \sigma$ (σ). This means that any bias due to systematic errors have been corrected for by CONTRACTOR. If not otherwise specified, 2 σ is basis for all accuracy figures

2.1.2 System of measurements

The SI (System International Units) shall be used in all relevant measurements, processing and reporting

2.2 Abbreviations

ROV	Remote Operated Vehicle
DGPS	Differential Global Positioning System
WGS-84	World Geodetic system 1984
C-O	Computed minus observed values
LBL	Long Base Line System
MF	Medium Frequency
UHF	Ultra High Frequency
PAN	Programmable Acoustic Navigator
HPR	Hydroacoustic Positioning System
USBL	Ultra Short Base Line System



VRU Vertical Reference Unit

MRU Motion Reference Unit

Additional terms and definitions utilised herein are defined elsewhere in the relevant contract documents.

3. Positioning systems

This section describes the required positioning of the main subsea positioning systems. These systems shall be integrated to the main survey computer in order to provide the most accurate and reliable absolute position of the surface and subsurface equipment.

No uncalibrated equipment, including cables, antennas, printed circuit boards, etc., shall be used during any part of positioning. All equipment in use shall be within the specifications laid down in this document, or if not specified, within MANUFACTURER's specifications.

3.1 General

3.1.1 Transducers

Transducers shall be installed on-board the vessels according to MANUFACTURER's procedures. A plan of locations of all the acoustic transducers and their co-ordinates referring to a fixed reference point (e.g. the USBL offset point) shall be produced.

A high quality motion sensor (motion reference unit) shall be used to compensate for transducer movement.

3.1.2 Calibration

Calibration of the positioning systems, including all spare equipment, shall be carried out by the CONTRACTOR or he shall ensure that the calibration of each individual equipment from SUB-CONTRACTORS or SUPPLIERS is properly performed.

If a specific calibration procedure is not referenced or included in this document, the MANUFACTURERS instructions and guidelines shall be followed.

Field calibration shall be performed both pre- and post-field work. Depending on the length of the field work; COMPANY may require additional field calibrations during the course of the work.

CONTRACTOR shall ensure that the following general procedures and requirements are adopted during calibration:

- No uncalibrated equipment, including cables, printed circuit boards, etc. shall be used during any part of the position fixing.
- Each calibration set-up shall last for at least 20 minutes and the data shall be logged for processing and reporting.
- The results of the calibrations, including relevant information on equipment settings shall be presented to COMPANY for review and acceptance. The report shall include measured minimum, maximum, mean and standard deviations for each measurement, and recommendation for operation figures. Any odd figures, anomalies or apparent erroneous measurements shall be highlighted and explained in the report.

- If, after further examination of results, doubt still exists as to the integrity of any equipment, CONTRACTOR shall replace the faulty equipment with similarly calibrated equipment prior to start of the survey.
- In the event that positioning equipment must be repaired or circuit boards are changed (that is not initially calibrated), and if such actions alter the position information, a recalibration shall be performed.

3.2 Water column parameter

The application of the correct speed of sound through sea water, is critical to the accuracy of the acoustic positioning. Sound velocity is a function of temperature, salinity and density. All three properties change randomly and periodically therefore regular measurements for velocity changes are required.

A Salinity, Temperature and Depth profiler shall be used to determine the (ray path) propagation velocity of the sound through sea water. CONTRACTOR shall use equipment able to supply the required information and shall overcome specific deep water problems if needed.

The computed sound velocity value or profile shall be entered into the appropriate acoustic system and it is the responsibility of CONTRACTOR to ensure all procedures are properly followed and results correctly applied.

3.2.1 Field procedure

A velocity value or profile shall be obtained at the beginning of the survey and thereafter at the discretion of the COMPANY.

- Observations shall be made at suitable depth or intervals during descent and ascent through the water column. The velocity profile shall be determined with the value at common depth agreed within ± 3 m/sec otherwise the observation shall be repeated. The sound velocity at the sea bottom level shall be determined within ± 1.5 m/sec.
- Having observed and recorded these values, a computation of the speed of sound shall be made. The methods and formulae to determine this value shall be presented to COMPANY.

3.2.2 Calibration

The temperature/salinity/depth probe shall have a calibration certificate verifying that it has been checked against an industrial standard thermometer in addition to testing against a calibrated saline solution. Strain gauge pressure sensor certificate shall be also supplied.

The serial number shall be clearly indicated to ensure the correct coefficients are applied. Only calibrated equipment shall be used.

3.3 Acoustic Long Base Line (LBL)

3.3.1 Description

LBL, or Range/Range acoustic navigation, provides accurate position fixing over a wide area by ranging from a vessel, towed sensor or mobile target to three or more transponders deployed at known positions on the seabed or on a structure. The line joining a pair of transponders is called a baseline. Baseline length varies with the water depth, seabed topography and acoustic frequency band being used, from more than 5,000 m to less than 100 m.

The LBL method provides accurate local control and high position repeatability, independent of water depth. With the range redundancy arising from three or more range measurements it is



also possible to make an estimation of the accuracy of each position fix. This factors are the principle reasons for a major increase in the utilisation of this method, particularly for installation position monitoring.

LBL calibration and performance can be improve significantly by using “intelligent” transponders. This devices are allow to calibrate arrays by making direct measurements of the baselines, acoustically telemetering the data to the surface equipment for computation and display. They also reduce errors inherent in the conventional LBL due to ray bending effects, as measurements are made close to the seabed where propagation changes are generally slight. In addition they can be supplied with environmental sensors to monitor the propagation conditions.

3.3.2 Field procedure

The system shall be operated by personnel with documented experience of LBL operations, to the highest professional standards and MANUFACTURERS recommendations.

Local seabed acoustic arrays shall consist of networks with at least 6 LBL transponders.

UHF array(s) shall be used for the installations with the highest requirements for accurate installations.

The system shall also include:

- A Programmable Acoustic Navigator (PAN) unit for interrogation of LBL transponders
- Transducer for vessel installation
- Necessary cables and spare parts.

All equipment shall be interfaced to the online computer.

The online computer system shall be able to handle the LBL readings without degrading other computation tasks.

The software routines shall allow for an efficient and accurate use of all LBL observations and in particular deal with the problems encountered in surveying with a LBL system.

The vessel's LBL transducer shall be rigidly mounted.

The operating frequency for the required MF system is typically 19-36 kHz.

The operating frequency for the required UHF system is typically 50-110 kHz.

The MANUFACTURER's installation/calibration and operation manuals shall be followed at all times.

A minimum of five lines of position for each fix shall be available at all times.

3.3.3 Calibration

After the deployment of the array a local and an absolute calibration shall be performed by CONTRACTOR.

The procedures for testing LBL transponders, deployment, transponder mooring, calibration and operations shall be submitted to COMPANY for approval.

As part of the local calibration, at least 20 (10 each way) base line measurements (between all transponders in the array) with a standard deviation of less than 0,5 m (2σ) for MF and 0.2 m (2σ) for UHF, shall be achieved.

Further, a "grid-on-grid" calibration shall be performed and the standard deviation in the final adjustment shall be less than 1.2 m (2σ) for MF and 0.3 m (2σ) for UHF.

F-test, W-test and MDE results based on statistical testing shall be provided as part of the adjustments and results.

Nearby structures and/or previously installed reference structures shall be included in the array(s) when possible and accepted by COMPANY.

3.3.4 MF/UHF LBL transponder

The LBL transponder shall be latest generation with the following minimum requirements (data presented as MF/UHF):

- Transducer beam shape: Hemispherical/Hemispherical
- Frequency range: 19-36 kHz/50-110 kHz
- Acoustic sensitivity: 90 dB re 1 micropascal/90-125 dB
- Acoustic output: 192 dB re 1 micropascal at 1 meter/190 dB
- Pulse Length: 4 ms/1 ms
- Timing resolution: 1.6 microsec./8.14 microsec.
- Depth rating: according with the project requirement

At least two of the transponders in each array shall include depth, temperature and conductivity options.

The MF transponder set-up shall include anchor weights (min. 80 kg) attached to the release mechanism on the base of the unit by a strop (preferably nylon to avoid corrosion) of 1.5-2 metres length. A synthetic foam collar shall be used as buoyancy.

The UHF array set-up shall include frames with transponders rigidly installed in e.g. baskets 2.0-2.5 m above the seabed.

The deployment shall be performed with special procedure in accordance with the sea bottom depth. The set-up shall be visually inspected by ROV after installation.

Concrete reference blocks or other transponder stands for MF arrays may be required by COMPANY.

3.4 Acoustic Short Base Line (SBL) and Ultra Short Base Line (USBL)

3.4.1 Description

SBL systems conventionally replace the large baselines formed between transponders deployed on the seabed with base lines formed between reference points on the hull of a surface vessel. The three or four reference points are marked by hydrophones which are typically separated by distances of 10 m to 50 m and connected to a central control unit. Seabed locations or mobile targets are marked by acoustic beacons whose transmissions are received by the SBL hydrophones. It is more convenient than the LBL method because multiple transponder arrays and their calibration are not required, however position accuracy is lower than the LBL method and decreases in deeper water or as the horizontal offset to a beacon increases. Additional factors as vessel heading errors and roll and pitch errors are significant in the accuracy measurements.



In the USBL, the multiple separate SBL hull hydrophones are replaced by a single complex hydrophone which uses phase comparison techniques to measure the angle of arrival of an acoustic signal in both the horizontal and vertical planes. Thus a single beacon may be fixed by measuring its range and bearing relative to the vessel.

Although more convenient to install, the USBL transducer requires careful adjustment and calibration. A compass reference is required and the bearing measurements must be compensated for the roll and pitch of the vessel. Unlike the LBL method, there is no redundant information from which to estimate position accuracy.

3.4.2 Field procedure

A Super Short Base Line (USBL) system, with tracking and latest generation of fixed narrow transducer, shall be used. A HIPAP (High Precision Acoustic Positioning) or similar system may be proposed to COMPANY for review and approval.

This subsurface positioning system shall be integrated with the online computer system to provide an accurate and reliable absolute position of transponders and responders.

The CONTRACTOR shall supply all necessary equipment in order to have a fully operational USBL system interfaced to the online computer for integration with the surface positioning systems and which meets the operational requirements set forth in this document. The installation of equipment shall comply with MANUFACTURER's requirements, and special attention shall be given to the following requirements:

- A system check shall be performed by MANUFACTURER within last 12 months prior to fieldwork. Documentation to be submitted to COMPANY for review.
- The installation and calibration of the acoustic positioning system shall provide an accuracy better than 1 % of the slant range.
- The hull mounted USBL transducer shall be located such as to minimise disturbances from thrusters and machinery noise and/or air bubbles in the transmission channel or other acoustic transmitters.
- The USBL equipment shall be supplied with its own computer and display unit, capable of operating as a stand-alone system.
- The Vertical Reference Unit (VRU) shall be of a fabrication recommended by the USBL MANUFACTURER and installed as recommended by the MANUFACTURER.
- The system shall be capable of positioning at least nine transponders and/or responders.

3.4.3 Calibration of the USBL system.

Calibration and test of the USBL and VRU shall be performed by CONTRACTOR according to latest revision of manufactures procedures and this specification.

If any main component in the USBL system has to be replaced, a complete installation survey/calibration of the system must be carried out. A representative from the MANUFACTURER shall be onboard if such a survey/calibration shall be performed and any necessary corrections of offset/delta values shall be implemented.



The calibration/documentation shall be divided into two phases:

- **Harbour calibration:** According to MANUFACTURER's procedures. Results shall be presented to COMPANY one day after completion and prior to field work.
- **Field calibration:** If any heading change (vessel) occur during measurements, at least 0.5 hours is required to settle the gyro prior to next set of measurement.

This field test shall be conducted as follows:

- The average value for the sound velocity in the whole water column and at transducer depth shall be implemented in the USBL system prior to start of the field test. Depending of system, the velocity profile for the whole water column may be implemented.
- The vessel shall be positioned above the transponder and rotated through 360 degrees. During this operation the vessel must be kept within a horizontal distance of 20 % of the water depth. While "sitting on top" of the transponder both USBL and surface positioning readings shall be logged (min. 400 measurements) to check for errors in the antenna/reference point offsetting.
- The vessel shall be located as stationary as possible in all four quadrants, same heading, with the reference transponder in centre. The horizontal distance shall as a minimum be equal to the water depth and the heading of the vessel shall be the same at all four locations (pref. EW or NS). The logging period on each location shall be approx. 10 minutes (min. 200 measurements) and both surface and acoustic positioning shall be logged. From these observations CONTRACTOR shall derive any transducer alignment error, acoustic scaling error and errors in the VRU.
- The vessel shall run, at normal survey speed, a minimum of two line (90° spaced) across the reference transponder with all corrections implemented as a final check of the calibration. The heading of the vessel shall be the same as when performing the four quadrant measurements.

All results shall be presented on scatter plots, histograms and listings to COMPANY for review/acceptance showing measured positions of the transponder including an identification of the vessels heading.

Firstly the results shall be presented with no corrections for the USBL system. Then the data will be reprocessed with the calculated corrections applied to verify the results.

The final scatter shall have 95 % of the measurements within a radius of 1 % of the slant range (transponder reference position in centre).

Results to be presented to COMPANY prior to start of any survey activity.

3.4.4 USBL transponders and responders

Type of transponders, number of transponders, frequencies and beam widths shall be approved by COMPANY for each vessel.

3.5 Acoustic - Combined LBL and USBL systems

A combined system may be proposed to COMPANY as an alternative acoustic system.

4. Contingency plan and spares

In general, all the equipment on-board shall be supplied with adequate spare parts for ordinary maintenance and repair. However, some equipment components and units are regarded as vital



for maintaining an efficient survey spread and the ability to operate. These equipment components or units may need a 100 % spare part supply onboard or a full back-up unit to meet the operational objectives. CONTRACTOR shall submit a list of spare parts or back-up units for COMPANY approval.

The list shall be divided into three categories of equipment:

- Equipment which a full back-up unit. This will be equipment which is part of a system which will suffer a 100 % breakdown in case of equipment failure.
- Equipment which needs 100 % spare parts. This will be equipment which will suffer a 100 % breakdown in case of failure in the components in question.
- Equipment which will require adequate spare parts supplies. This will be equipment not critical to maintain full operability and efficiency or equipment in redundant number on-board already.