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POSITION FIXING REQUIREMENTS OF THE OIL INDUSTRY

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INTRODUCTION

A mere fifteen years or so ago, when most offshore oil-related activity was still in fairly shallow water and but a few miles beyond the horizon as seen from the coast, position fixing at sea was still a very uncertain business, dependent on very careful operation of valve driven radio positioning devices and dedicated manual recording and plotting of data. When one looks around now and observes the instrumentation which is available to measure, compute, display and analyse positional data, and the ever-increasing demands which are made on it, one can only be amazed but gratified that sea surveying has had its share of technological advance. Of course technological development is not unique to positioning equipment and methods, but undoubtedly it has been given a considerable fillip by its association with the oil industry. General navigators would never have made the same demands for long range accuracy and performance, and naval and inshore surveyors would not on their own have provided the impetus or market to encourage manufacturers to develop the very wide choice of equipment nowadays available to the offshore surveyor. But offshore oil exploration and development finance, as viewed from the standpoint of the surveyor, appears limitless and only a very small proportion of it has been needed to stimulate the effort put into bringing new positioning equipment and methods into operation. Clearly, if the oil industry urgently needs something with which to further its developmental aspirations, and the economics of a project promise the required return on investment, the finance and effort which can be supported to develop vital tools is immense. Although offshore positioning is but a small facet of the activity – albeit an important one, as this paper hopes to demons-

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trate – it has been very well supported by the industry; not by direct finance, although this has sometimes occurred, but by creating a small but demanding market in which innovators who can produce equipment needed to satisfy a critical requirement in time for the operation can obtain a good commercial return for their labours. One may confidently remark that the oil companies and the position fixers, whether surveyors or equipment manufacturers, have greatly assisted each other. However, the provision of positioning services is highly competitive and those in the business really have to stay ahead of the competition to survive, since outside the oil industry and the similarly capital intensive inshore dredging business, there is perhaps little to support flourishing positioning equipment or service enterprises. Unlike the land survey and mapping technology developed for the US Army, and putting aside the US Navy's Doppler satellite, there seems to have been little in offshore positioning which can be said to have been primarily sponsored by the military in peacetime, though the principles of such modern instrumentation originated through wartime necessity and Shoran has only recently faded from the scene.

What, then, are the offshore position-fixing requirements of the oil industry, how have these been satisfied, and what else is expected for the future? We may consider separately the systems producing the raw positional data, and the equipment and software used to process, display, record and analyse it.

It is probably true to say that the more the industry gets, the more it wants, and if asked what positioning output would totally satisfy the oil companies the answer might be along the lines of cheap real-time digital multi-range or pattern output providing guaranteed absolute accuracy of ± 1 m for 24 hours each day, for distances up to 500 km from shore, and with a frequency and spectral bandwidth which can be conveniently licensed world wide. While such a powerful system might satisfy all the industry's sea surface positioning demands it is clearly not necessary for every operation. Nor will it be possible to apply the same system as is used above the water level at the sea bed, and an increasing amount of engineering positioning demands the latter. So we are essentially concerned with both sea surface positioning and sea bed positioning, with the exploration phase requiring the former and, following discoveries, the development operations increasingly requiring sea bed positioning methods. Future deep-ocean mineral mining or dredging, in which many major oil companies already have a stake, will also require stringent sea bed positional control of both survey and recovery tools.

EXPLORATION REQUIREMENTS

Offshore hydrocarbon exploration normally begins with marine seismic survey, whereby ships trail lengthy cables or streamers along a grid of lines, firing energy discharges at regularly-spaced intervals and recording the echoes received from the substrata by the sensors or geophones within the cables, for subsequent sophisticated digital processing. The positioning aids carried are required to control the shot point interval to a high degree of relative accuracy, to steer the ship along the programmed lines, and to record the positions of the shot points. In order to be able adequately to combine the seismic data from a succession of shot points into a positive representation of strata of depth – a procedure known as tacking – it is vital that the distance interval between shot points is maintained as accurately as possible and a tolerance of under ± 2 m for a shot point interval of 25 m is normal. This relative accuracy is rarely achieved directly from the positioning system output, but comes from a time base set according to the velocity of the ship which is sensed usually by sonar doppler or derived by means of the smoothed positioning data. Guiding the ship along pre-programmed lines is usually a less critical problem, except for 3D seismic, which requires the utmost absolute accuracy in order to know the precise positional relationships of all shot points within the seismic grid.

Finally, the required accuracy of the absolute position of shot points within the survey area is normally governed by the purpose of the survey and the stage the exploration of the area has reached. Thus reconnaissance seismic is said to have very low absolute positioning accuracy requirements since it is merely designed to determine if further exploration work is justified. Satellite navigation, preferably with – or sometimes without – sonar doppler, will do; several hours without passes may be tolerated, and the normally very open grid will be positionally accurate perhaps to no better than a few hundred metres. Further interest in the area decrees further selective seismic survey on denser grids infilling what has been previously obtained. This may be followed by a yet further detailing seismic survey before a potential drilling location is pinpointed. As interest quickens, so concern with positional accuracy intensifies and invariably methods used for the later stages of the work look for high repeatability. The problem arises when the older seismic work, where the seismic quality may be very high, is integrated into the newer grid and inevitably, because of its different positional specification, there may be misties and confusion. Ideally, therefore, one should use a single highly repeatable system from the outset of exploration, though without unnecessarily exceeding the positional accuracy demands of the seismic process. Initial seismic exploration is, until stratigraphical energy velocities are better known, a somewhat crude instrument for exploration, albeit one of the best, so there is no need to overelaborate on positional accuracy demands at this stage. Nonetheless we require a wide-coverage, 24-hour, multi-pattern, multi-user system capable of a minimum positional accuracy matched to the seismic output of ± 50 m or thereabouts.

Such a system is also adequate for the subsequent positioning of drilling rigs to drill structures defined by the seismic and, if successful, for the further positioning of appraisal wells on the same seismic and geological evidence.

After the first well there exists a new situation, since one then has information with which to refine the seismic velocity data and, in turn, the seismic and geological interpretation. And, if the well turns out to be a discovery, the impetus exists for detailed seismic survey with finer positional definition.

The oil companies used Decca Navigator and limited-cover Hi-Fix chains for many years in the North Sea, and Shoran and Raydist were at the same time well to the fore elsewhere. All effectively provided only two lines of position and there were often uncertainties of several hundred metres in absolute position. In the early and mid-70's there was additionally a surge of integrated Doppler satellite systems for seismic survey, their operators and proponents seeking to exploit their convenience, independence from shore-based positioning systems, and the full-day-operating capability that they gave the industry, but tending to gloss over the actual shot point positional integrity which they supplied, and the fact that a discrete absolute fix was only available every 1-2 hours, and that of an accuracy indicated only in statistical terms. Generally, in this respect, one could only draw accuracy inferences from the static performance of Doppler and satellite update discrepancies, and this shortcoming contributed to a growing awareness that we really had very little idea what level of performance in determining the positions of shot points we were getting from our mere two-pattern positioning systems with no redundant or uncorrelated repeated observations. Hence the development in the last few years of systems providing a redundancy of position lines and thus a means of real-time determination of the positioning accuracy being achieved on the mission and the performance of the system. Further, the concept of repeatability on which we had been obliged to focus our attention as a measure of system performance in two-position-line circumstances became subordinate to the standard deviation of a three or multi-position-line fix which is now possible.

Thus for general oil and gas exploration purposes we now require from our positioning system a minimum of three well-conditioned independent lines of position which we may receive over a wide area for 24 hours a day, and which is sufficiently stable to provide position fixes at intervals of 10 seconds with standard deviations in the lines of position within ± 25 m. We feel we have such in modern systems like Pulse/8, Argo, Hi-fix 6, though this is not to say that we are totally satisfied with the present level of performance, in which progressive improvements are being made and presumably will continue. With Navstar promising fix accuracies of ± 10 m on demand in a few years, it is likely that we have seen the design of the last new medium-to-long-range shore-based radio positioning system, and can look only for improvements in the accuracy and reliability of those which now exist, until such time as Navstar with receivers/processing packages at extremely competitive prices makes them all redundant.

When we require improved accuracy, as in the later stages of seismic survey, there are available the shorter-range portable high frequency ranging systems. The only problems then are in finding suitable stations within system range of work area for the responders and obtaining an operating licence from the licensing authority. Here again, the trend has been towards real-time processing and analysis of three position lines to provide precise track control, shot point position control, and final shot point positions.

While Doppler satellite has been relegated to a reserve role in all but reconnaissance seismic (though some oil companies may still be prepared to accept it for much of their initial seismic work) the use of the basic system in static mode for verifying rig positions and determining radio positioning system base station co-ordinates has become standard practice. For the rig position verification check on the radio or acoustic positioning system, the point positioning by broadcast ephemeris is perfectly adequate. Moreover, it is at least as accurate as the seismic survey-derived knowledge of the position of the reservoir several thousand metres subsea. One must also remember that the anchored rig will be subject to lateral movement during the period of fix verification at least to a similar order as the accuracy of the point position fix itself. This implies the unsuitability of anchored rigs as base stations for short-range radio positioning systems though many circumstances may leave operators with no alternative and thus the unavoidable degradation of the ensuing position fixing which the use of a short-range positioning system was designed to improve. Only when the base stations are on platforms can we be confident in the system output, but here simple Doppler satellite point positioning will not provide a consistent basis for the radio system either in absolute or relative terms. We need to resort to translocation methods or conventional land survey methods to relate base stations to each other and to adjacent land stations where the required geodetic datum manifests itself. In this domain the oil industry is in some difficulty, such has been the uncertainty of the last two years over what the commercial Doppler satellite receivers and software have been delivering.

We do not have, nor do we need to have, ready access to precise ephemeris. Nor, indeed, is it desirable to spend longer to merely record the one or two satellites for which it is generated. We thus wish to be certain of the geodesy and output of the commercial satellite instruments using broadcast ephemeris and we therefore look to the geodesists for definitive advice.

ENGINEERING DEMANDS

So far this paper has tended to concentrate on the positioning requirements of the exploration phase of the oil industry's activity. However, once an oil or gas field has been discovered and proved commercial, the engineering development becomes even more demanding in respect of positioning, particularly for the newer schemes involving large sea bed installations remote from the personnel platform, but also for the platforms themselves and their associated pipelines. Engineers fasten things together which have been designed to fit, so that the positioning of individual components in a production scheme requires the maximum possible accuracy in positional measurement. Moreover, except where sea bed conditions dictate otherwise, pipelines are required to follow the straight-line-shortest-distance between turning points, so minimising the length of steel tube laid. The first North Sea pipelines laid under rather loose Hi-fix control, whereby barges followed pre-laid buoys, demonstrate a wavy track influenced by strong tidal current acting on the buoy markers and the barge during its forward laying progress. Positional control had to be tightened, and Brown and Root in particular moved towards onboard track control by more accurate range-range systems, initially Electrotape over line-of-sight range, then Raydist, which was not very successful, but the experience from which led to Argo and its multi-user, 3-pattern, range-range onboard output.

In localised platform and well-head work, the emphasis is now on relative position – relative to an already emplaced platform, to another piece of sea bed steelwork, or to previously drilled test boreholes. Development work, particularly for small fields and in deeper water, is increasingly on the sea bed at depths often well in excess of 100 m so that surface positioning in some operations is largely irrelevant. Not entirely so, since surface vehicles handling pieces of the underwater installation have to be positioned in order to be able to place the pieces correctly, but the positional control of these pieces, 100 m or so below the crane, in relation to others they have to mate with, presents a relative positioning problem which may be only part covered by visual guidance by divers. Further, pipelines laid from the surface reach the sea bed a considerable distance behind the lay barge and their precise emplacement requires positional control at the sea bed on the pipe itself. Seabed measurement of the position and orientation of one item relative to others thus requires a totally new family of instrumentation and techniques.

Acoustic transponder systems have provided the solution and their application to the positional control of localised surveys and site investigations by coring vessels, submersibles and deep-towed survey sensor fish are now well established. Use of transponder arrays is designed to guarantee continuity and consistency between sea bed positions of survey data, penetration test points, core borings and the position of the platform, its satellite installations and its feeder and export pipelines. By attaching relay transponders to coring tools, the platforms themselves, pipe ends during laying, and other sea bed units, one can obtain positional control remotely with relative accuracies of better than ± 5 m. How much better depends on the extent of the array, how well it is calibrated, the operating frequencies of the system, sea bed conditions and operating circumstances. Even more refinement in both performance and operating techniques is promised through the use of so-called intelligent transponders, and engineers may look forward to derived dimensions quoted and repeated to an accuracy of ± 0.1 to 0.2 m. To obtain this during 1978 and 1979 has needed divers using taut wire gear and underwater gyro compass or repeated measurements by the Ferranti inertial system, both very expensive in terms of support equipment. In 1980, if one can produce with certainty the same results from high frequency acoustic transponder arrays allied with relay and intelligent transponders on the items of subsea equipment which require to be placed, there will be considerable savings. There is thus ample scope for development in the performance and techniques of acoustic measurement, particularly for applications to ever deeper water activity.

SYSTEM CALIBRATION

So long as the operating conditions of a chain remain stable and the units remain the same, the general expectation is that the positions derived from that chain will be consistent within certain limits. The repeatability of the system at the one sigma level is the indicator normally used as the measure of the system capability and published performance contour diagrams. However, repeatability is no longer an acceptable criterion for employment of a system on a project. Offshore exploration operators now need to be satisfied about the absolute accuracy of the positional data produced, and this may only be measured and evaluated through calibration of the system. Short-range and compact line-of-sight systems with pulsed signals are normally calibrated by adjustment at the mobile unit to deliver accurate ranges over a known base line such as a triangulation side. While pre- and post-mission calibration is a normal practice, there are obvious difficulties when base and mobile units have to be substituted following breakdown, since to break the survey for beacon collection and calibration is extremely inconvenient and costly.

For the longer range systems with large non-portable transmitter units and masts such calibration is not possible. Calibration must necessarily take place within the coverage in order to select a signal propagation velocity to minimise the errors within the coverage and to identify the residual errors in the patterns throughout the cover. Formerly this has been an uncertain and prolonged process, only possible where fix comparisons could be made against a more accurate or equivalent system and where it was difficult to separate random and systematic error components. Static Doppler satellite fix comparisons on rigs and platforms introduced more positive data but their distribution is sparse or, in the early days of a chain, non existent. Three position lines will inevitably produce triangles of error which cannot be satisfactorily resolved merely by adjusting the propagation velocity, since this may merely increase the problem elsewhere in the cover. Calibration at discrete points throughout the cover can be made from a tightly moored ship or, where deep water prevents this, by laying a Doppler fixed acoustic array and making a comparison against this. Whatever the method, operators will be anxious for the data sooner rather than later, particularly for an intended permanent chain. Calibration of temporary chains, such as caesium standard Lambda, Argo or Sea-fix, for an exploration seismic survey, may be cursory and sparse against Mini-Ranger or Trisponder, but adequate in the circumstances. A compromise between academic desirability and practical economics must always be struck but it is probably true to say that there has been continuing inadequacy in the calibration of medium and long range radio positioning systems which the oil industry, itself partly to blame because of past disinterest, would like to see rectified.

DATA RECORDING AND PROCESSING

Alongside the developments in radio positioning and acoustic hardware the industry has, as in other fields, experienced tremendous advances in the automatic logging of positioning data and in the on-line real-time reduction and analysis of the data.

Contrast the situation of a mere ten years ago, where surveyors had to write down the readings from two or more oscillating pointers on dials or rotating counters, plot the position on a lattice chart, and, perhaps in the absence of the skewed display track plotter, direct the helmsman back on to the preferred line and repeat the routine hundreds of times per shift – only, at the end of the operation, for an oil company geophysicist to infer through seismic misties that he must have been a lane or two out.

Nowadays manual recording is replaced by automatic data logging at pre-set fix intervals, the data recorded may include several patterns from one or more systems, some of it may be computed and used to drive a true rectangular grid track plotter display or helmsman's left-right indicator, and in addition the data may be analysed for consistency, weighted and computed to a least squares best position, all in the interval between fixes or shot points. What room for improvement here ? Well, the capability outlined, although possible, is not general and those with the capability have not always had the surveyor's requirements as a basis for the clever things which modern desk-top calculators and microprocessors can do with the raw data.

The first requirement is reliability – guaranteed, 24 hours per day. A tall order, perhaps, but often only provided by 100 % backup of units which of course have to be paid for. One often feels that the search for innovation has not allowed time for the pursuit of reliability in a model before its successor is on the market.

Secondly, adaptability, whereby the user has a choice of output options and real time analysis of the positioning data and is not restricted to the hard-wired invariable output of a dedicated microprocessor. Different users may wish to use all possible appropriately weighted positional data, others may prefer to stick to the theoretical best system covering an area and record others as mere reserve backup. Some users may wish to see a continuous display of the positioning system performance during a line; others may only require an analysis of positions achieved on a line at the end of it.

Thirdly, clients would like to minimise the time between completion of survey and completion of final plot and report. Some contractors can already produce a full-size onboard plot which the client may carry off the ship with him. Rarely is this essential, since the positional plot without the interpreted data to go with it merely indicates the survey coverage. However, particularly for seismic survey, a speedy processing of positional data into the final post-plot map and data tape, together with an analysis of the accuracy of the data, is a requirement of the industry which is yet to be universally satisfied.

Fourthly, this particular writer would like to make a plea for the data logged during the mission by mini-computer-controlled line printers to be presented in a much more readily and immediately understandable form than the various writers of software nowadays permit. Client representatives often have difficulty in sorting out the wheat from the chaff and would welcome improved clarity in the headings and in the data output representing system performance.

In conclusion, it is evident that we have come a long way in a decade and the operators of positioning equipment have found themselves in a very competitive business where there has been a steady tightening of requirements by their principal clients, the oil companies and their contractors. Progress has been rapid; often, perhaps, too rapid, in that matters such as calibration, reliability, proper survey of shore stations, and positive lane identification, have frequently suffered, but I feel we are now in a period of consolidation where renewed attention to these may be given and, in some circumstances, permit real competition with Navstar, the full operating arrangements for which are still uncertain.