Calibration of an underwater acoustic distance measuring instrument

N. C. KELLAND

Mr Kelland

As a result of the operational success of the prototype Rangemeter and the relative positional accuracy (± 20 cm) achieved by IOS during an underwater study of the mobility of a sand wave crest, the British Petroleum Co. Ltd purchased the first production model for an underwater survey in its West Sole gas field. The new Rangemeter incorporates a 4 digit visual display and operates with up to five transponders.

57. The transponders were deployed in special frames on the sea bed near Platform WB at West Sole, and the distances between each pair were determined using the Rangemeter. Ranges were then established to each transponder from a number of survey points approximately 5 m apart along the sea lines adjacent to the platform. Measurements were also taken from positions above buried sections of sea line. In this case the measuring points were established with the diver-operated Pipelock system developed by Mobell (Marine) Ltd. Ranges were also determined from the platform legs. All the results were logged on a tape recorder mounted in a BP designed underwater housing. A computer program was written to calculate the optimum position of each survey point, and its relative accuracy, and a map was constructed to show the distribution of the sea lines relative to the platform. Provided ranges are measured to more than three transponders, the program will eliminate a range value which gives an accuracy outside a predetermined value. The ranges measured during the survey varied between 60 and 450 m, and the relative positioned accuracy of most of the survey points was calculated to be within ± 20 cm.

Dr R. L. Cloet, Scientist, The Institute of Oceanographic Sciences

I should like to congratulate Mr Kelland on his achievement in making measurements in the North Sea.

59. I was pleased when he joined the Institute of Oceanographic Sciences (IOS) at Taunton to find that he would undertake the trials with this position system himself because for some years I had gradually been becoming more and more disturbed by the way in which people took measurements at sea. I have seen a water intake for a power station designed on the basis of two depth soundings near to each other with the history of the level of that particular point worked out on the basis of half a dozen soundings spread over a hundred years.

60. This situation made me feel it was essential to get to grips with site investigations and positioning as distinct from navigational positioning. This is precisely what Mr Kelland has done. In the event the movements of sand waves were so small that they nearly always fell within the positioning errors of the surface navigation systems. Work on these is still continuing and I have great confidence that both for diver work

and remote work positioning, it is one of the major measurements which have to be improved still in site surveying.

Mr P. L. Stuart, Engineer, The British Petroleum Company Ltd

British Petroleum has a vast programme of construction and civil engineering work offshore. It is taking engineers all their time to devise methods of training and acquiring further knowledge under water. The same job task and basic training techniques are needed to do the same thing under water as on land, and land surveying now has to be carried out under water.

62. There is a problem in the southern North Sea on the West Sole gas field, where BP is undertaking a programme covering a number of years of modifications to the existing steel structures. Construction is by a jack-up barge, standing on the sea bed on six gigantic legs jacked down from a floating pontoon. This has to be towed into place, and winched into position on anchor lines with the help of tugs. It is likely to stamp on the sea bed, particularly on the gas pipelines, so the barge has to be manoeuvred into position with great care to carry out structural works on the platform driving heavy piles.

63. BP's standard methods of survey, of diver held tape, grid lines, etc., i.e. the more primitive means, was not thought to be reliable and efficient. Sonar scanning was considered a possible aid and some trials were carried out in 1974. This gave us some measure of success but it still did not give us the degree of accuracy of positioning these pipelines close to the structure. Mr Kelland's Rangefinder equipment seemed to offer some measure of success in overcoming the problem. It has been developed with the help of the instrument manufacturer and the diving contractors involved in a most efficient manner. From the outset the job was defined—what was needed within the parameters of distance and accuracy—then the equipment was assessed. It had to be developed within a relatively short time. Time in the oil industry is of the essence.

64. The instrument had to be tested, and lastly, but by no means least, a team of divers had to be trained. All these steps were undertaken in the relatively short time of 6–9 months. BP now has an accurate plot, and can undertake and develop the civil engineering field work with some degree of confidence. This underlines the success and the hard work that Mr Kelland has provided. BP sees a great potential for the equipment in other allied areas of activity under water and is obviously interested in monitoring the behaviour of the terrain—the sea bed—particularly close to the structures.

65. As structures get larger and in deeper water the need to be very clear on what is happening round the structural foundations becomes vital. There is much development to be done and many uses to which this equipment can be applied successfully. I should like the Author to comment on future applications.

Mr C. J. Partridge, Designer, Sonardyne Ltd

In developing the Rangemeter, problems were encountered at an early stage in evaluating the accuracy of the instrument. The original method was to attempt the comparison of an underwater baseline with an accurate land baseline by means of a co-ordinated theodolite observations of taut line buoys. The logistics of this method proved too difficult. Thereafter the method chosen and developed by Mr Kelland was the evaluation of the internal consistency of the acoustic measurements alone. I would like to congratulate Mr Kelland on the efficient manner in which he has investigated the accuracy of the Rangemeter by this method.

67. In dreaming of future improvements attention must be given to simplicity of operation. In the present model, measurements of distances of less than 20 m proved troublesome due to reverberations. A new model has now been designed which eliminates this problem and also eliminates the problem of long-term drift in the calibration of the electronics. In particular, the 'turn-around delay', or inherent signal processing delay in each transponder has to be accurately set and also com-

pensated for in the Rangemeter. These time-delays are now generated by quartz crystals and hence virtually free of all calibration problems.

68. Further improvements have been suggested, such as the incorporation of a micro-computer to calculate X and Y co-ordinates of the diver's position. Given the necessary development funds this is quite feasible, but such sophistication would need a larger pressure housing to incorporate the extra controls, keyboard, etc. Therefore it should be reserved for use on a transport vehicle or submersible.

69. It is important to bear in mind that as an engineer one may have little idea of the possible applications of an instrument. For instance, I imagined that one situation where it would be impossible to use this instrument would be on a sea bed of shifting sand where stable transponder positions would be a problem. Mr Kelland has proved that this is in fact a valuable application in the investigation of sand waves, and all further information which comes back from the field is awaited with interest.

Mr B. Park, Commercial Diver, Bix Diving Co. Ltd

From the diver's point of view the good feature of this piece of equipment is its ease of handling under water. This is very different from many new gadgets which divers are given to use. It is compact with a minimum of 'Christmas tree' equipment on it to carry around with you. My company had a small frame which we used to place on the pipe so that we could get accurate readings between all the transponders. There were no real problems. Compared with the old way of using tape and wires, etc., it cannot be beaten.

Mr R. Goodfellow, CxJB Ltd, London

What has come over here is that clearly at last there has been conversion of ideas into reality, and this was followed up commercially. One point in my own activity is that while there are plenty of bright ideas, commercialization seems a dirty word. This is an area under water where Britain starts on equal terms with its competitors, and is competing in an international field. UK technology is becoming commercially viable, so let us have more of it.

72. Things have come a long way since my early training days as a diver, when communication was with a rope tied to the diver's waist, but there is still a need for engineering know-how under water and research must continue. It needs people who can see the problem at first hand.

73. I am sure that Mr Park will agree that from the diving point of view it would still not be possible to operate under water a mass of batteries and wires, even if one was assured that it was the most fantastic device. On average it seems to take about three times as long to do anything under water as on land, and it probably costs something like five times as much to the people paying for it. With that margin there is scope for more imagination and engineering.

74. Perhaps the best would be turn the system inside out and record the position on the surface while letting the man down below get on with his work.

Mr M. J. Kenn, Imperial College London

By making simultaneous observations from two sufficiently sensitive acoustic-measuring instruments located at opposite ends of a line oriented in the flow direction, it should be feasible to determine instantaneous stream velocities. If such data were continuously recorded, it would then also be possible to ascertain (for design purposes) the horizontal components of 'orbital' motions stemming from storm waves in the North Sea, and elsewhere. At present there appears to be a dearth of such information.

76. Would the Author, and perhaps Mr Partridge comment on these proposals and indicate how any practical difficulties might be surmounted.

Dr Cloet

I should like to assure Mr Kenn that further developments are continuing. Getting these developments into the hands of the engineer is a tradition which was started at Taunton and is continuing. The IOS is working with Mr Partridge on an underwater positioning system which he has designed for us. With this it will be possible to read the position of a towed vehicle directly on the ship's deck, so the vehicle can be unmanned and position itself accurately as it moves over the bottom of the sea, or perhaps as it stands to take a core, for instance. This work is in hand and is now a practical proposition.

78. There is an acoustic doppler meter in existence—in fact there are now several of them. I suggest a better way of dealing with this is by using an electro-magnetic current meter. These have been used to measure orbital velocities of waves even on beaches just to the seaward side of the breaker zone. Recently in America one of these electro-magnetic current meters was placed on positioning transponders so that the velocity of the water at the reference point transponder stations could be measured continuously. This gives a good instantaneous reading, but it has some drift in it. Principally what one is interested in is instantaneous reading. These instruments are available; I am not sure what the commercial position is, but certainly measurements can be made.

Mr J. Bailey, CxJB Ltd, London

With the increasing importance of inspection and maintenance of off-shore structures, it would seem it would be useful to be able first to fix a position on a structure, and Mr Kelland has demonstrated this instrument will do that. However, the developer might want to return to that position at a later time. Has Mr Kelland any idea of the way this system could be used to navigate the diver back to the original position that has been fixed?

Mr V. Lawford, Institute of Oceanographic Sciences

In reply to Mr Kenn, acoustic measurements are being made at the moment off Lowestoft. There is also on the market a Norwegian instrument which has been undertaking trials off the coast of Norway. They have measured wave orbital velocities with this instrument, and I believe that there are others around.

81. As someone who has used the earlier model of Mr Kelland's instrument may I ask one point. A problem I found was in communication, in actually recording the data. I feel it would be worth considering the recording of data inside the instrument. There are on the market fairly small memory units and one would envisage a simple push button control to record the last digit that comes up.

Mr Partridge

The acoustic method referred to is not a doppler method, it is a time of flight method. It is in fact superior in principle to the doppler method in that it does not depend on the sound velocity.

83. On the point of recording data, plans are in hand for ability in the new instrument to output a serial data stream which represents the number on the doppler so this can be recorded directly into a cassette recorder via a cable up to the surface. I agree it is possible in principle to use a solid state memory inside, but there is too little space inside the instrument and it is short of power. But there is a bigger problem. If there is a number on that instrument it is necessary to record what it represents. It would be fairly easy to add another couple of digits to identify which transponder it refers to. But what position or reading does it refer to? In the case of a diver who moves along a sand wave, it is an identifiable transit, so it would be just a series of numbers; but if the diver is wandering over the sea bed plotting things at random, a tape recorder would be needed to identify what the particular set of readings refers to.

Messrs P. A. Watt and D. J. H. Lewis, Dept of Electrical Engineering, University of Tasmania

We wish to comment on some of the operational and precision aspects of the Rangemeter system described by Mr Kelland, and to point out some comparisons with another diver location system.

85. In February 1975 we were involved in the development of an ultrasonic underwater survey system for use in mapping the debris of the Tasman Bridge over the River Derwent in Hobart, Tasmania. Three sections of the bridge totalling 128 m in length collapsed on 5 January, 1975, after being rammed by the 10 000 dwt *Lake Illawarra*. Restoration required re-piling amid the debris of the bridge and the ship, which sank in the immediate vicinity of the collapsed sections. Mapping the debris was hindered by the limited visibility (0.2–2 m), the depth of water (20–43 m) and currents up to 6 knots. Survey by mechanical means proved very slow, inaccurate and unreliable when divers' sense of direction had to be relied upon.

86. The diver location system developed for this job was required to work over ranges of up to 100 m and used 150 kHz ultrasonic transducers as fitted on small craft echo sounders. A transmitter carried by the diver acted as a source of 150 kHz bursts, the times of emission being controlled from the surface via a cable taped to the diver's air hose along with his telephone line. The ultrasonic signals emitted were received at the four corners of a 10 m square buoyant platform anchored several metres below the surface, with corner posts projecting above the surface. The platform was positioned over the area of interest and its location accurately fixed by surveying the corner posts. The position of the diver relative to the platform was found by simultaneous measurements of the transit times of the 150 kHz ultrasonic bursts from the transmitter to each of the four receivers. With the receiver array above the diver, line of sight transmissions were possible for most locations amid the chaotic debris on the river bed.

87. No underwater baseline was required for this system, and all control, supervision and data logging functions were carried out on the surface. In operation, the diver's position could be rapidly computed and plotted, and his description of the debris used to build up a map. The ability to plot, guide and supervise the diver's progress from the surface, and to correlate his findings with other data during the dive, was found to be crucial in maximizing the amount of useful engineering information which could be obtained in the limited dive time possible in the depth of water, and we consider this a major operational advantage of the system.

88. The four transit time measurements allow a consistency check (or tolerance) to be computed (any three readings being sufficient to locate the diver in three dimensions below the surface). This gives added protection against multi-path reception. The accuracy attainable with the 150 kHz system, especially in the plan co-ordinates, appears to be a little better than with the Rangemeter, even under tidal conditions and allowing for uncertainties in the variation of river temperature and salinity with depth. The principle reasons for this are the shorter wavelength used and the elimination of the rather long transponder response time and its associated uncertainty. In the 150 kHz system the timing accuracy was limited by the signal envelope rise time (and hence by the system band width), by the signal/noise ratio at the detector (which controls the threshold level) and by small delays in exciting the transmitter.

89. The plan co-ordinates of the diver are, for the geometry used, relatively insensitive to small constant delays added to each of the transit times. The ability to locate the transmitter by four simultaneous measurements, rather than via two successive transponder measurements, eliminates inaccuracies which may result if the diver moves or must reorient the transmitter between the two measurements. For three-dimensional work, this problem using transponders is aggravated even further.

90. Mr Kelland has mentioned the problem of outboard motor noises in the acoustic environment. At the Tasman Bridge site, we have experienced no difficulties in the vicinity of 150 kHz due to operation of outboard motors, tugs, jet boats, diamond

drilling of sunken roadway, or any other motor-driven machinery on barges. The only spurious noise source which did cause difficulty during a short period of time while using the 150 kHz system was a periodic interfering signal of similar frequency which we believe was due to an acoustic fish finder being operated on a fishing boat about 2 km distant from the bridge site.

Mr Kelland

The diver location system described by Watt and Lewis was only required to work over ranges up to 100 m. Consequently it could be designed as a short baseline method and as such is a useful addition to underwater surveying techniques. It does not, however, supersede the Rangemeter system, which was designed to operate over ranges up to 500 m. Also, because the Rangemeter is used with seabed beacons it is more flexible, since the baseline lengths can be chosen to suit a particular survey requirement.

92. The other important advantage of a Rangemeter type of approach to detailed seabed mapping is the absence of any wire link to the surface. Although it can be an advantage to plot and guide the diver's progress from the surface, any system using a cable to the diver will severely limit the area which can be covered during a dive. Although this presumably did not pose any problems during the Tasman Bridge survey, since the diver was also using an air line, it is suggested that in other shallow water applications the wire link used by Watt and Lewis could be replaced by a diver-towed surface radio beacon. A similar requirement on a Rangemeter survey, viz. on-line monitoring of a diver's progress, was satisfied using a through water communication link between the diver and surface.

93. Undoubtedly the major advantage of the Watt/Lewis method is that the seabed survey can accurately be tied into the local survey grid. However, the relative accuracies of the two methods are similar, despite the frequency difference: it is now common practice with the Rangemeter to determine four transit times from each survey point, and relative accuracies better than ± 0.10 m have consistently been achieved over ranges up to 200 m. This improved accuracy has been achieved by practically eliminating the uncertainty from the transponder response time and by making accurate determinations of the propagation conditions, although, as pointed out by Watt and Lewis, it is important to minimize any errors introduced by movement between successive range measurements. This problem is overcome by marking each survey point. The latest Rangemeter, as used by British Petroleum, was also completely unaffected by extraneous noises, such as those associated with outboard engines or demand valves.

94. The Rangemeter has been frequently used by a diver to navigate back to a previously surveyed position, and the standard instruction exercise adopted with commercial divers is to teach them to navigate under water in 1 m visibility to a marker having known range values.

95. Mr Stuart's question on future applications has to some extent been answered by the comments raised by other contributors, and I believe it has now been clearly demonstrated that acoustic surveying systems can be used in conjunction with divers to conduct detailed engineering site surveys and seabed investigation, not only better than alternative methods, but in far worse operating conditions.