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FUTURE OF HYDROGRAPHY – THE PROBLEMS AHEAD

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First of all, I would like to lend a measure of credence to what I have to say by telling you of my last 17 years as a surveyor in the offshore exploration and production industry. It is an unfortunate fact of life that only surveyors themselves seem to be able to understand that there are fine differences in specialisations in the profession. For instance, in 1965, after 17 years as a hydrographic surveyor involved mainly in charting for maritime safety, I found myself, having been recruited as a hydrographic surveyor, measuring an oil storage tank to determine its volume. This is not the easiest of tasks because they are not hollow; the tanks include pipe work, inspection ladders and such like, all of which occupy a portion of the volume. My problem was made worse in that only a week or two beforehand I had been largely occupied in command of a survey vessel running lines of soundings and the formula for a volume of a cylinder was something of which I had to remind myself. Such, however, was the training of hydrographic surveyors, even in those days, that I am pleased to relate the task was completed to everyone's satisfaction, the true state of my ignorance never being revealed from that time until now. You will note, therefore, that my professional life has been divided to date neatly into two equal parts – for 17 years I was in what I describe as pure hydrography, and the latter 17 years in the kaleidoscopic surveying world of the oil exploration and production industry. The work consists of, but is not restricted to, as contractors often put it, acting as a sort of sub-routine in a large computer system : the surveyor is called upon to assist at various stages in the exploration and production venture, and I will just run through some of those stages.

It starts with the award of concessions (see Fig. 1) when an oil company is allocated acreage for exploration and the first problem is one of basic mapping,

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finding out what has already been done, what charts are available, what original surveys have gone into them and defining the boundaries of the new acreage to make sure that these are properly described in the legal documents. Then we move into the exploration stage and the surveyor is immediately concerned with accurately positioning the seismic surveys. After the interpretation of the seismic detail, and when it has been decided to drill a well, then positioning the drilling rigs that drill the holes. It is, of course, essential to make sure that you have the same or similar accuracy for both of these activities.

In the event that a discovery is made the surveyor moves on to the next stage; site surveys are needed for the next round of drilling and for any platforms that may be placed on the structures for development drilling and extraction of the product, and route surveys for pipelines from the platforms to the land. Thence we

AWARD OF CONCESSIONS

Basic Mapping/Projections
Boundary definitions

EXPLORATION

Positioning : Seismic surveys
Positioning : Drilling rigs

CONSTRUCTION

Site surveys
Route surveys
Dimensional control of construction
Platform installation

DEVELOPMENT

Pipelaying control
Well deviation
Production seismic
Safety
Communications

MAINTENANCE

Pipeline inspection
Submersibles positioning
Underwater control
Settlement and Tilt
Miscellaneous

Fig. 1

move into the world of land surveyors and engineering surveyors: dimensional control of construction of platforms. In the North Sea these are not constructed just in one place. For instance, one of those put in last year by my company was partly built in Japan, part in France, part in Scotland, part in Ireland and, as you can see, it behoves everybody to make sure that each bit slots into the other when the time comes to assemble them all together.

The secret of that one is to make sure that no two pieces are completed at the same time. As one is completed you measure it up and move on to the next one, making sure that they are going to be compatible. The platform itself has to be installed in the same place as the soil boring and site investigations have occurred, which is a tricky survey/navigation problem.

Next we are into the development of the oil field, and we have to control the laying of pipelines into the platforms along preselected routes, making sure that the lay barge does not deviate away from the wayleave. On board, of course, there will be a sophisticated survey system and team of surveyors to make sure that this objective is achieved.

From the platforms wells are deviated outwards in a circle around the platform; 20 to 40 wells are drilled under survey control into the sub-surface targets selected by the geologists.

Production seismic surveys entail a much finer grid of seismic lines and in this day and age 3-dimensional seismic surveying requires a very precise navigation: lines of 25 metres apart, which is the equivalent of large-scale surveying but out of sight of land.

Then there is the question of safety: once you have laid pipelines in to the platforms, vessels have to anchor up adjacent to them. The accommodation on platforms is not extensive, so quite often we have a "flotel" ship sitting alongside a platform, and the surveyor's task is to make sure that its anchors are dropped in a safe manner so that they do not damage the pipeline network. Anchors are run out under survey control, which is a new technique all of its own developed in the North Sea.

Communications: one of the many odd jobs that come our way is lining up the tropo scatter antenna dishes for radio communication.

On the maintenance side: every pipeline that is lying on the seabed has to be inspected each year by one of two methods: from a submersible, or by side scan sonar to see if any changes have occurred in the seabed and if any damage has occurred to the pipe, such as whether the pipe has been washed out underneath and is in a suspended state. For that we are required to go into the whole subject of submersible positioning, something which occupies a great deal of time because we have to correlate the position of the submarine or the submersible with the surface positioning system and tie it in to the underwater control and precise measurements for engineering work under the surface. Every platform has to be measured annually for settlement and tilt. I am pleased to say that ours are not settling very fast and we have not seen any tilting as yet!

Finally there are the miscellaneous surveys that come the way of any surveyor who finds himself in this side of the profession. These may range from setting out golf courses and hockey pitches to housing estates. Indeed, one rather surprising one came up recently – it appears that helicopter pilots in Norway have a different idea about where the H on the helicopter landing deck should go, compared with their fellows who fly the helicopters from the United Kingdom. It was a surveyor who was asked to set out two sets of H's on the helideck using welded studs to indicate where they are, so that as the vessel moves from one area to the other they can paint in the H in the right place.

So the expertise that is needed is not only hydrography but land surveying. A lot of land surveyors move into the offshore world, some of them even describe themselves as hydrographic surveyors. The oil industry surveyor will have to undertake dimensional control, hydrography, geodesy (when we are dealing with long distances), satellite fixing, satellite navigation, oceanography, meteorology, applied acoustics, and data handling (which is a large part of our business). Thus a wide spectrum of expertise is needed.

Before I move on to the next part of my paper, I will give you an indication of the sort of vessels we use – they are usually vessels of convenience, often spot-chartered. One of the good spin-offs, perhaps, of the downtrend in the long-distance fishing industry in Europe has been freeing up of good ships such as stern trawlers which can be easily and rapidly converted into very useful survey vessels.

Soon, and certainly before the next International Hydrographic Conference, I shall be completing my active involvement in the survey profession. I am due to retire next year after 35 years at the front end of the business and therefore this is my opportunity to do some crystal gazing and see what lies in store for the offshore surveyor of the future as his work sites move inevitably into ever deeper water.

Just to highlight the problem, we are commonly working on the continental shelf, where most of the problems have already been overcome. We are moving into the shelf-break (see Fig. 2) and a lot of problems occur there which are yet to be solved. It will not be long before we are on the continental slope and the continental rise, and who knows what is going to happen if we have to mine in the abyssal plain. These are the points I want to touch on.

Clearly, if problems can be anticipated then possible solutions can be investigated before the pressures of urgency force not-always-practical, ad hoc solutions on those responsible for acquiring the data : by that I mean the hydrographic surveyor. This may well be a mundane statement – but there are none so blind to the obvious as those who are not involved in having to think of the problems.

The tendency in the past has been to use tried methods and systems to the limit of their capability and beyond, the methods and systems having been developed to solve the problems of a previous generation of activities. Examples of this approach are rather like the "Peter" principle : promotion to the level of incompetence. This can apply to equipment just as much as to people.

(i) The use of 2 MHz phase comparison radio positioning systems which were superb in their time, were developed for inshore coastal surveys and then were used for far offshore exploration surveys, with all the attendant problems of sky-wave, night effect and loss of lock in remote unreferenceable areas.

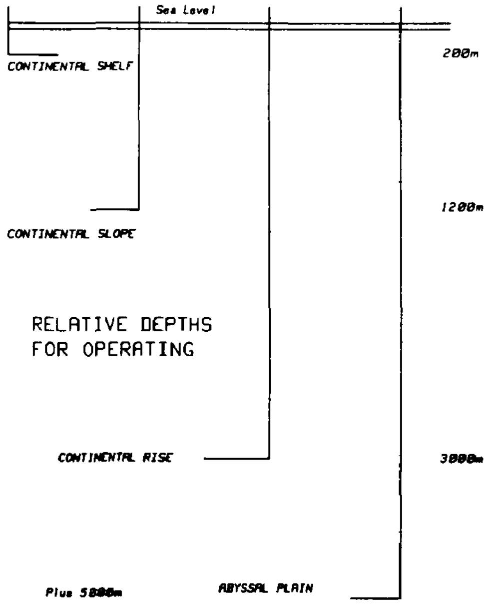

FIG. 2

(ii) The use of 100 kHz phase comparison navigation systems for something they were never intended for, which is for higher precision of survey control. The problem is that the data, acquired under these circumstances, stays on record for many years, is extracted 10 years later and the user believes in it.

(iii) The usually unsuccessful attempts to use self-recording tide gauges designed for deployment in protected inshore sites in exposed areas offshore.

(iv) The measurement of water depths which are critical for engineering design in quite deep water by means of echo-sounders with wide beams through water columns of unknown or indeterminate characteristics.

(v) The use of graphical solutions for positioning measurements stemming from the days of optically measured position lines long after multi-line radio positioning became available.

(vi) The ever increasing pressure to use acoustics through the water for various end results utilizing, inevitably, equipment of a previous generation.

Thus there has been a history of technology never quite catching up with present-day needs. My hope to-day is to try and forewarn you of the needs of the future.

I am almost certain that in deeper water the principle of remote sensing from the sea surface will not provide sufficient accuracy for engineering requirements; therefore it is necessary to get down to the sea-bed to have a look at it and take measurements.

This requirement is hampered by a very proper reluctance to put men below the surface unless it is absolutely necessary. Even then the requirements for safety and rescue in case things go wrong make, or will make, such an exercise hideously expensive.

The deduction is therefore clear : the surveyor's instruments will be carried on some form of remotely controlled submersible. Indeed, this is already the case and tethered remote controlled vehicles (Fig. 3) are commonly used for precise engineering work.

It is not the province of the surveyor to invent such vehicles but, in order to keep the cart behind the horse, it is prudent to make sure that the surveyor's and the final user's needs are clearly in view while innovative basic design work is in hand. What are our requirements ? (Fig. 4).

- The location of the vehicle within and relative to the work area must be precise.
- The sensing tools must determine the following values :
  - Physical characteristics of the water column.
  - Differential height above a datum plane.
  - The height of the datum plane below LAT.
  - The position, size and shape of all sea-bed features.
  - The characteristics of the near-surface sea-bed sediments.
  - The bottom current.
  - The size, shape and condition of engineering structures.

When I first embarked on thinking about this problem, I did not realise that this particular wheel was so well on the way to being invented. I discovered that work is in hand in various research organisations to evolve a Free Swimming Submersible and it is with some measure of confidence for the future that my investigations proved this to be the case. I felt, however, like Archimedes would have done had he discovered that someone had beaten him to it in the bathroom.

TYPES OF VEHICLE UNDER DEVELOPMENT

FREE SWIMMING

The most exciting development. These vehicles may be autonomous or under the control of an acoustic link from the surface or a submerged control centre.

TETHERED AND GARAGED

Already operational in shallower water, these may be extended in depth capability.

TETHERED MOTHER PLUS FREE-SWIMMER

A combination of the two techniques. The umbilical from the garage is dispensed with thus increasing the range of operation.

FIG. 3

THE SURVEY REQUIREMENTS

POSITION : Absolute for coarse grained repeatability. Relative locally in work area.

ELEVATION : Depth below sea surface and relative elevation of sea bed.

SIZE AND SHAPE : Obstructions, structures and events such as damage.

SEDIMENT : Type and thickness; buried objects.

MEDIUM CHARACTERISTICS : Temperature, salinity, velocity, chemistry and biology.

MEDIUM MOVEMENT : Direction and rate of horizontal and vertical flow.

FIG. 4

Which brings me to a very important point that I would like to raise at this juncture : how is it that such important developments as these can take place without a reasonably "up-to-date-in-his-thinking" surveyor knowing anything at all about it. It was only after realising that the FSUS was a very strong possible route that by enquiry I found I was not alone ! But who, one asks, is solving the survey problems ? Or are we to have yet another generation of high-cost equipment which does not fulfil the accuracy requirements needed.

What are these submersibles that will carry the survey instruments of the future ?

The present vehicles are either manned, that is, a midget submarine, or operated unmanned via an umbilical carrying power, communications and data. Of these latter there are again two types : the first is in direct communication with the mother-ship, the second is lowered in a so-called "garage" and operates via this tether umbilical.

Figure 5 shows one of present generation of manned submersibles. It is surrounded by its means of propulsion, its buoyancy, and by the tools with which it is going to be working; a very expensive piece of equipment and, although they operate quite safely, there is always the ever present need that safe practices have to be constantly exercised in their use.

Figure 6 represents a larger remote-controlled vehicle which is not free swimming, but is operated by a tether via an umbilical and is to be deployed over the stern of the mother ship. It is unmanned and has quite a payload of observation equipment and working tools. This is a well known workhouse in our industry : the RCV 225, which operates from a "garage". This cage in which it is housed is lowered down to its working area and the submersible swims out from the garage

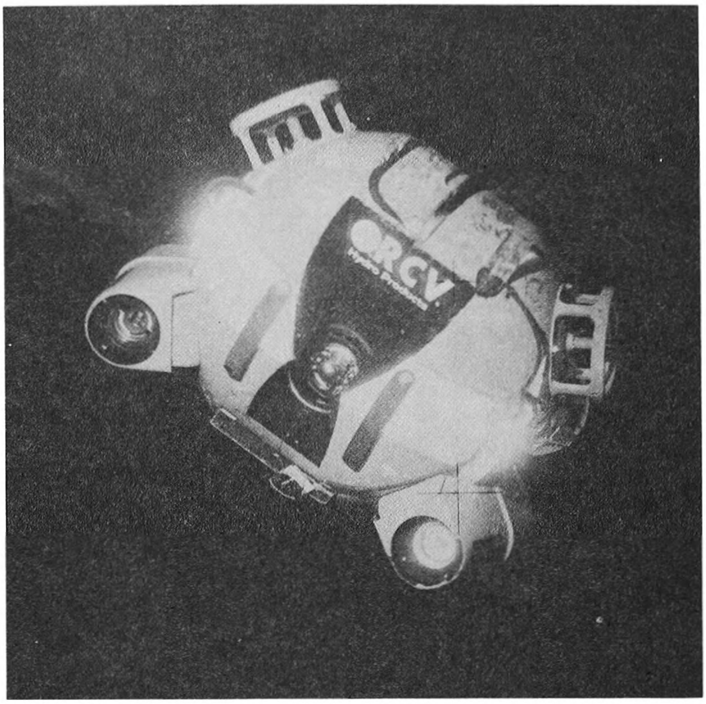

FIG. 5

on a tether and its payload is simply a television camera. I have quite often used these to observe divers while they are operating.

Those, then, are the vehicles we are using today. The future generation will be essentially the same except that the sensing vehicle may be untethered. It may be controlled by acoustic links or pre-programmed to operate entirely independently.

A surprising amount of active research in such vehicles is in an advanced state. Figure 7 shows those which were highlighted at the Symposium on unmanned, untethered submersible technology at the University of New Hampshire in 1980. Clearly, some of them are already aimed at the very deep water capability and some of them are already a reality – *Epaulard* for instance, had, by last year, completed 50 dives; *Eave* (*East*) has successfully tracked a pipeline without any surface intervention and is this year programmed to transit a structure and take video pictures of it as it goes through.

At the same time as vehicle development, so associated technology is advancing (see Fig. 8).

Data links to transmit slow scan television pictures at a rate of 1 frame/second by means of acoustics are now possible. The field of artificial intelligence to replace the human decision-making capability is a fascinating development. It is, in fact, computers programming computers programming computers.

Our very great problem is the replacement of the tethered vehicle's remote power supplies with a power-pack of sufficient endurance to complete a task at

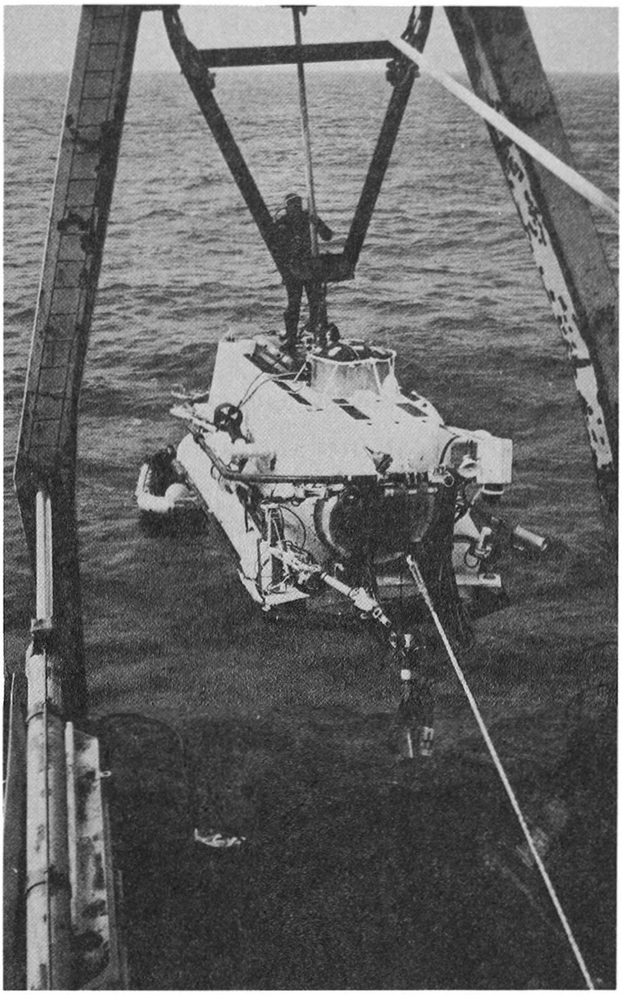

FIG. 6

ACTIVE RESEARCH AND DEVELOPMENT

Sponsor	Organisation	Vehicle (Depth)
UK SRC	Heriot-Watt	ANGUS 003 (300 m)
US Navy	NRL Washington DC	UFSS (500 m)
NK	CNEXO	EPAULARD (6 000 m)
US Geol. Survey	NOSC San Diego	EAVE (WEST) (700 m)
– do –	MSEL, UNH	EAVE (EAST) (1 000 m)
US Navy	NOSC San Diego	AUSS (6 000 m)
NK	MIT	ROBOT (100 m)
NK	HYDRO-PRODUCTS	RCV 150 (600)
ARPA	APL Washington Seattle	SPURV I, II, III (1 500-3 000 m)

FIG. 7

NEW TECHNOLOGY

Area	Subject
ACOUSTIC LINKS	SLOW SCAN TV AND SONAR
IMAGE PROCESSING	1 FRAME/SEC RELIABILITY
ARTIFICIAL INTELLIGENCE	DECISION MAKING PLANNING RECOGNITION OF TASK
ENERGY STORAGE	LITHIUM POWER SOURCES
MICRO PROCESSORS	MORE POWER AND MEMORY
CONTROL SYSTEMS	DESIGN AT EARLY STAGE
NAVIGATION	SHORT RANGE LONG RANGE INERTIAL

FIG. 8

depth (it takes a very long time to swim it down several kilometres and bring it back up to the surface).

It is not by any error on my part that the two items 'Control Systems' and 'Navigation' are shown as the last of the list of New Technology. There is much concern that the former is not being given sufficient priority until too late a stage of vehicle development. The latter, please note, is surveying but not even referred to as such. Let us hope that surveyors with the right experience (or even surveyors with any experience) are involved in developing the 'navigation' and measurement capabilities of the new vehicles and tools.

It is beginning to be realised that navigation of submersibles to a high degree of accuracy is achievable by means of inertial techniques. The principle of I.N.S. has long been used for conventional navigation of vessels and aircraft. Precise surveying by submarine is undoubtedly at its best using Inertial Navigation and the only limitation to it being used in a remote-controlled vehicle is its size and weight and the requirement for it to have velocity inputs.

For land survey control, in Canada particularly, they have been using inertial systems with most satisfactory results to provide three-dimensional accurate coordinates. As you will know, it is necessary to stop at regular intervals to permit the system to re-settle or input a precise position to up-date the I.N.S. Some interesting developments of this last technique could be considered : television or acoustic imagery of pre-programmed structural information can be recorded as the vehicle moves adjacent to a structure on the sea bed. This may provide an X, Y, Z, relative to a point on the structure, or dX, dY, dZ. Either set of parameters can be the velocity input to the I.N.S. for up-dating. Work is also being carried out on continuous-wave short-range doppler acoustics to provide accelerations along- and cross-track for a vehicle traversing very close to the sea-bed. Under such circumstances normal pulsed doppler acoustics are not effective.

So, it can be seen, technology is far from dormant in the world of hydrographic surveying. My last 34 years in the profession have been a strange progression from the seemingly archaic to the electronically magical world of to-day's seabed surveying, in which reliable equipment of all kinds are interfaced together with powerful computers, where ingenious software produces the result in any number of different forms : maps, charts, video screens, magnetic tapes, print-outs. Is it always correct ? My task latterly has been to check whether it is right – and the answer is that it is not always so !

The reason, as often as not, is that SURVEYORS have not been closely involved in the system development and what comes out is the engineer's or mathematician's ideas of what is needed. Whatever clever things may be said and done with filtering, smoothing and statistical analysis – it all amounts to 'Pushing the FIX' : a thing the true surveyor does at his peril !

Thus I hope that my brief message is clear : appreciate what modern technology can achieve; let us involve professional surveyors in development and, finally, remember the Surveyor's lot in life : "We are the last to be told what is going on – and the first to have to do something about it !".

And somehow we have to keep the survey precept to the forefront : "All measurements must state the condition of quality and reliability".

DISCUSSION

Adam KERR (Canada). – I felt that in your paper you talked about the future of hydrographic surveying and not the future of hydrography, because I think that the problem we are going to face is one of data manipulation – it is going to be one of the most significant problems of the future, and the actual data gathering is another problem. I don't downgrade it as a problem, but I think it is one of the problems. I also felt that you were talking about small surveys, small precise surveys, rather than large area surveys and that is a problem that differentiates, in most cases, the oil industry from the national Hydrographic Offices. Much of the submersible type of technology lends itself very well to the small area, precisely surveyed, but because of the speed of operation, the general economics, the power supplied, it does not lend itself very well to covering large areas.

Now, one of the matters that I thought you should have talked about was that of the acoustic properties of the ocean. You talk about moving from remote sensing from the ocean surface down to the deeper depths; you actually do your measurements from that and, of course, one of the main considerations there is to get into a homogenous ocean – there where you are not going through the different density layers. In any of the remote sensing, as you call it, from the ocean surface, that is the problem – a very major problem that we are all faced with – side scan, and everything like that – to get down below the thermocline into that more homogenous thing : equal density area. I note it because it is so new that you probably were not aware that work is going on in Canada – a company called

International Submarine Engineering Ltd. in Vancouver are involved (at the moment) in a lot of submersible development – remotely controlled submersibles and, in particular, they are working on a system which we call ARKS, which is for working under the ice. One of the problems in Canada is to get into areas where we suspect that very large tankers will go at some time, but our survey ships can't go there. So we feel that we can put a vehicle through a hole in the ice and then survey underneath – it is one way of going about it – but the problem that arises up there is that in the Arctic you get a tremendous amount of density layering with the fresh water under the ice and also the problem of reverberations of the acoustic signals between the ice surface and the bottom of the ocean there. At the moment we are carrying out tests to try and find out how difficult that problem is to handle. But what we are looking for is a certain element of speed of the vehicle, and most of the remote vehicles at the moment are rather slow-travelling. We are not looking for something at 18 knots or anything like that, but then again we are looking at something significantly better than 2 knots, so that we can cover a reasonable area of the seafloor. I think that is really what I wanted to say. I will be pleased to talk more to you about this afterwards – about the ARKS development – it is very early, and you say the surveyors are the last people to be informed – well, of course, we are surveyors, but because it is so early in development we are cautious; it may be a failure. The reason we have to believe in success is that the University of Washington had a system earlier, one which they used in the Arctic ; it did not have the same area coverage or the same speed that we are looking for, but we think we can go from their technology outwards.

HASKINS. – Thank you very much indeed for your very interesting comments. In fact the acoustic problems of getting through the thermocline really precludes, to my mind anyhow, the use of acoustic commands for the control of an untethered submersible. There is a submersible being developed in the UK which is acoustically commanded and is fine for shallow water, perhaps, but in deeper waters it is a great problem. I highlighted this in my paper at FIG last August. As for the speed of the vehicles, they have increased in speed but the normal workhorses we are using have not increased in speed. The biggest problem is to overcome the velocity of the water, that is, the current. Agreed you can produce something with a working speed of 1 1/2 knots but we can't really deploy that in a 2 1/2 knot current.

Prof. SIMPSON. – I would like to ask the speaker if it would not have been more clear if he had mentioned the use of acoustic transponder beacons placed on the ocean floor, particularly when operating in such vessels as the deep-sea drilling ships, such as *Glomar Challenger*, which uses a 13 kHz acoustic transponder beacon, usually only a single unit, not necessarily two or three, so that no triangulation is required – the surveyor is dependent upon a direct beam and a phase difference in the acoustic pulse being received. One can position the ship in this way not only directly over the acoustic transponder beacon but also apply, by the use of a computer, a pre-determined offset and then maintain that offset while the drilling procedure takes place. Now in this respect I am talking about drilling in water of the order of any kind of depth and I don't mean any reasonable depth; quite commonly it is five thousand metres – five kilometres; exceptionally, it goes as deep as 10,000 metres; while the *Glomar Challenger* is maintained in position for several days on end drilling a hole in the ocean floor up to 2,000 metres below the sea floor. This calls for exceptional position-holding capability. The surveyor does not come into it really as such but the necessity here is to maintain that ship in such a position of constancy that there is no damage done to the drill string. The other point I wish to touch on was that the speaker mentioned as one of the problems as they get into deeper water being in the field of oceanography, and I wonder what he meant by the use of the term "oceanography" in that sense, which to us is rather a wide field.

HASKINS. – Your question there is the use of acoustic transponder beacons for the control of very deep drilling, for instance, the *Glomar Challenger*. Yes, it is clearly well known as an engineering measuring tool I would imagine – my understanding is that it has shortcomings in that the excursion of the control vessel in its dynamic positioning as related to that transponder is quite large and the riser is designed to accommodate a fairly large excursion – particularly when it has to move into very deep water. Clearly the primary method of surveying control on the sub-surface is an acoustic transponder array. I think you also mentioned oceanography, and what particular part of oceanography – well, I have discovered that oceanography is all things to all people; it is geology to geologists and seismology to seismologists – it is waves, it is physics, it is chemistry – and, collectively, it is oceanography. If you are a generalist like myself you have to have a thin, but wide, knowledge and be aware that you must go to the experts.

FIRST FITTING OF A PROPELLER IN MID-OCEAN

by Captain Desmond SHEEL, RD, FRGS, MRIN, MNI

THE TURRET STEAMER *Oak Branch*, under the command of the Nautilus Shipping Company's Commodore, Captain H.D. Sheel, left Yokohama for Sydney on 29 September 1897. On 10 October, when in 9° South and 154° East, a terrifying crash was heard, and it was found that the propeller was gone.

The engines were stopped, and at daybreak a boat was lowered, and while the Second Mate kept sharks off with a boat hook, the Captain examined the damage.

Sea anchor rigged

A sea anchor was rigged of spars and sails, but this was rapidly devoured by sharks. The second one used 80 fathoms of anchor chain and was successful. All fore ballast tanks were filled, but this was insufficient, and the fore hold was filled with 200 tons of water. This allowed the stern to lift clear of the water. Then the Second Engineer was slung overside in a bosun's chair to chip ragged edges away, while some of the crew threw wood to keep the sharks off, but they even ate wood.

The ship was now rolling heavily, and the floor ceiling in number one hold was torn up, and fears were expressed in case any of the planks came through the ship's side.

Lifting propeller over the side

The propeller was eventually lifted by gun tackle and chain slings. It was lowered to harbour deck and re-slung with three tackles. As the ship was rolling this proved a dangerous task, but eventually they got the propeller boss plumb with the tube and the shaft was forced through.

At length after seven-and-a-half days of non-stop work, the engines were started and observations showed that the ship had drifted 120 miles. They could plainly see cannibals on the beach of New Britain in Bismarck Archipelago.

In later years Captain Sheel used to carry a box, and he would ask people what it contained. They would say 'tobacco', to which he replied, 'No, this is the state of the floor ceiling when we eventually got under way, sheer pulp'.

Captain Sheel was still serving in 1907 when he was 70, and was in the Owners' office when he had a heart attack. He is buried in the Sheel vault in Sunderland cemetery. He received Lloyd's medal and others and also received testimonials. It must be borne in mind that in those days a ship had no radio; it was literally an isolated community, entirely dependent on its crew, and this feat of fitting the first propeller in mid-ocean is a landmark in nautical history.

Extract from : *Seaways, The Journal of the Nautical Institute*, September 1982, p. 19.